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Williston Reservoir Fish Assessment: Results of Hydroacoustic, Trawl and Gill Net Surveys in August 2000

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The Peace/Williston Fish & Wildlife Compensation Program is a cooperative venture of BC Hydro and the provincial fish and wildlife management agencies, supported by funding from BC Hydro. The Program was established to enhance and protect fish and wildlife resources affected by the construction of the W.A.C. Bennett and Peace Canyon dams on the Peace River, and the subsequent creation of the Williston and Dinosaur Reservoirs.

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ABSTRACT

Williston Reservoir is the largest body of water in BC and covers a drainage and surface area of 96,930 km^2 and 1,650 km^2 respectively. The reservoir first reached full pool in 1967 and underwent fisheries investigations in 1974-75 and 1988 or approximately seven and twenty-one years after completion. The Peace Williston Fish and Wildlife Compensation Program (PWFWCP) was formed in 1988 to promote conservation and enhancement of the remaining fish and wildlife resources. Fisheries efforts were directed at stream assessment over the first decade and then shifted to the reservoir by the late nineties. As a result, limnological and biological assessments of the reservoir were undertaken in 1999 and 2000 to establish baseline conditions for future monitoring. The biological component focused on assessing fish populations in the pelagic (deep water) zone, and included reconnaissance level hydroacoustic and trawl surveys and concurrent gillnet sampling. Estimates of the pelagic fish population and apparent species composition were made and results were compared with earlier investigations. A further objective was to evaluate standard large lake monitoring techniques developed in southern BC to this northern reservoir and make recommendations for future surveys. This report documents the August 2000 hydroacoustic and trawl survey results and comparisons with 2000 gillnet studies reported by Pillipow and Langston (2002).

The pelagic habitat area was estimated at 80,160 ha or 57% of reservoir surface area during August 2000. The abundance of fish in pelagic habitat was estimated at 5.92 (5.07-6.88 95% confidence level) million based on hydroacoustic estimates. Up to 2 million additional fish may have occupied the near-surface (0-2.5m depth) habitat of Finlay Reach resulting in a "best estimate" for the reservoir of eight million fish. The 1988 acoustic survey also had problems with under-estimating fish numbers near the surface and provided evidence that total populations in Williston may have declined slightly over the past 12 years. Trawl net catches and CPUE of 6-15 fish·ha^{-1} were extremely low due to low densities of fish. Trawling confirmed that mid-water habitat at night was occupied mainly by lake whitefish and kokanee and provided valuable information on length, age and length-at-age determinations for these species. Combined trawl and gillnet catches were used to calibrate acoustic size distributions and develop an initial estimate for kokanee based on their apparent age 0+ abundance. The gillnet results were extremely valuable in sampling surface habitat that was missed by acoustic and trawl sampling in 2000. Comparison of gillnet results to earlier investigations was useful in assessing the distribution of key species, determining their relative vulnerability to capture in gillnets and enabling some ballpark estimates on abundance.

Evidence is presented to suggest a current kokanee population of approximately one million fish (all ages) (0.8-1.3 million) suggesting a spawning population of 40,000-90,000 kokanee. The whitefish population was estimated at about 6 million in pelagic habitat and may be in the order of 10-11 million for the entire reservoir if evenly distributed as indicated by 1975 and 1988 investigations. Numbers of all other species

including rainbow and peamouth were more difficult to assess but may contribute less than 10% of total fish in pelagic habitat or less than one million fish. All estimates in this report are considered preliminary and require further work to verify.

Problems were encountered with lack of bathymetric mapping used for extrapolating fish density information, inadequate equipment (boats and navigation gear) and with accuracy of fish counts near the surface, particularly on Finlay Reach. Recommendations have been made for improved mapping, modifications to equipment and changes to sampling design which will assist in sampling critical near-surface habitat with acoustic and trawl gear in future. Due to the size of this reservoir and complexity of surveys required, a staged approach to further assessment has been proposed.

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BC Hydro provided electronic image files of pre-impoundment contour mapping. Bathymetric maps were assembled and merged with the TRIM map outline by Sean Cheeseman and Don Phillips of Ministry of Sustainable Resource Management – Aquatic Information Branch. Arne Langston and Brian Blackman of Peace Williston Fish and Wildlife Compensation Program provided assistance with logistics and initial contacts with individuals having local knowledge of the reservoir. Don Miller and Mike Lindsay of Kootenay Wildlife Services conducted trawl sampling. Tim Stiemer of Williston Lake Charters provided and operated a 24' cabin cruiser for conducting acoustic surveys. The Kyllos provided meals and accommodation at Finlay Bay camp (and some laughs). The manuscript was reviewed by Dr. Ken Ashley.

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INTRODUCTION

Williston Reservoir, formed by the W.A.C. Bennett Dam at Portage Mountain, is the largest impoundment and inland body of water in BC, and one of the largest in North America. The dam was completed in 1967 and the reservoir reached full pool level by 1972. Approximately 1,650 square kilometers of forested land within the Peace, Parsnip and Finlay river valleys were flooded and more than 600 kilometers of main stem and large river tributary habitat was lost. The lower reaches of numerous small to medium sized streams were lost as well. The pre-impoundment area was only minimally logged (i.e., edges and navigation channels) prior to flooding. As a result, significant efforts were directed to removal of floating debris for several years following impoundment, and many floating and underwater hazards still exist throughout the reservoir depending on time of year and pool levels. This hydroelectric project has had significant impacts on fisheries and other resources in the area. The biological productivity of the reservoir has been described as "Boom and Bust" with a 10 year "boom" period followed by a 20 year decline in productivity to its current oligotrophic state (Stockner et al. 2001).

Fisheries Assessments

A post impoundment fish stock assessment of the reservoir and its tributary streams was conducted in 1974-75 by Barrett, Halsey, Bruce and Starr. The reservoir study consisted of extensive gillnet sampling at ten near-shore stations to assess fish species composition and relative abundance (Barrett and Halsey 1985). A combination of floating and sinking gillnets set parallel to the shoreline to depths of 30m captured 14 species and over 15,000 samples in total. Lake whitefish (*Coregonus clupeaformis*) were the dominant species and the largest component of the gillnet catch throughout the reservoir. Bull trout (*Salvelinus confluentus*) and rainbow trout (*Oncorhynchus mykiss*) were the most prevalent game fish species captured. Kokanee (*Oncorhynchus nerka*) were found in very low numbers throughout the reservoir, but their numbers were predicted to increase as time progressed and the nutrient balance of the reservoir stabilized (Barrett and Halsey 1985). Biological information including fish size, age and size-at-age was established. The tributary assessment focused on determining the species diversity and distribution in tributaries to the reservoir. Important spawning and rearing habitat was identified and described for both stream resident and adfluvial species of fish. In total, 59 streams were surveyed and a total of 14 species and over 700 fish were sampled. Bruce and Star (1985) concluded that there was ample spawning and rearing habitat available to sustain current fish populations found in the tributaries and the reservoir.

Sampling stations established in 1974-75 by Barrett and Halsey were re-sampled by Blackman in 1988. In addition to near-shore stations, Blackman experimented with some off-shore gillnetting to assess pelagic fish populations. Off-shore sampling was done by sinking larger versions of the experimental gillnets used near-shore to depths of 5m below the surface in 60m of water. Blackman (1992) concluded that the species

composition and relative abundance had changed to favor species adapted to lacustrine habitat and that lake whitefish populations remained stable but fish size appeared to have declined since 1975. Riverine species such as mountain whitefish and arctic grayling declined to very low numbers presumably due to the change in insect production caused by fluctuating water levels and loss of riverine habitat. Species best able to utilize plankton such as kokanee appeared to be increasing in numbers and range throughout the reservoir. Apparent increases in the number of bull trout was attributed to the availability and increased abundance of forage fish.

As part of the 1988 investigations, Canadian Biosonics Ltd. conducted the first quantitative assessment of pelagic fish populations in Williston Reservoir using hydroacoustics. The study included three separate surveys and a mix of day and night observations to determine the most appropriate time of year and day to conduct surveys. An initial estimate of total population size was done and spatial and target size distributions were reported. Johnson and Yesaki (1989) concluded that the best time for acoustic surveys would be night-time during summer or early fall. Although acoustic surveys were conducted concurrently with gill netting, comparisons between results were never made.

Fish and Wildlife Compensation

The Peace Williston Fish and Wildlife Compensation Program (PWFWCP) was established in 1988 as a legal obligation to compensate for losses of fish and wildlife resources resulting from the power project. Objectives of the Compensation Program today are to conserve and enhance fish, wildlife and their habitat within the program area (BC Hydro website). The majority of fisheries projects undertaken during the first decade of the PWFWCP focused on stream work. During the late 90's there was a shift towards developing a better understanding of the reservoir. Two new priorities were to determine the current productivity of the reservoir and to assess the status of forage fish in the reservoir. A two year limnological study was undertaken in 1999 to assess reservoir productivity and compare with previous estimates when the reservoir was "younger" (Stockner and Langston 2000). In 2000 a fisheries investigation was undertaken to determine the current species composition and abundance in the pelagic habitat of Williston Reservoir. This investigation consisted of a combination of hydroacoustic and trawl surveys and concurrent gillnet sampling in deep water habitat. Due to the size and complexity of the reservoir, remoteness and lack of suitable equipment, it was decided that the initial fisheries investigations be considered reconnaissance level and include an evaluation to determine if standard monitoring techniques used on southern BC lakes are applicable to Williston Reservoir. Upon review of earlier acoustic work it was concluded that the preferred timing for these surveys would be during the new moon period in August to take advantage of maximum pool level, good weather, medium length nights and thermal stratification of the reservoir. Specific objectives of the acoustic, trawl and gillnet surveys were to:

1. Provide baseline data for determining the abundance and species composition of forage fish in pelagic habitat of the reservoir;

2. Evaluate the usefulness of standard large lake fish stock assessment techniques used in Southern BC i.e., hydroacoustic and trawl sampling;
3. Determine if gillnetting information can be useful for interpreting hydroacoustic information in pelagic habitat and;
4. Recommend methods for further assessment of fish stocks in Williston Reservoir.

This report summarizes the results of the August 2000 acoustic and trawl surveys and includes a discussion of the 2000 gill-net survey and comparison to 1988 acoustic survey results.

Definitions

The term "pelagic" in this report uses the definition according to the Collegiate Dictionary of Zoology (Pennak 1964): "of or pertaining to the open waters of the sea or lakes, especially where the water is more than 20m deep." Based on this definition we have partitioned the habitat into "pelagic" defined as 20m depth or greater and "near-shore" which is less than 20m depth at the time of survey. The near shore habitat includes the littoral areas (generally >7m depth) and also the 7-20m depths.

Study area description and mapping

A detailed description of Williston Reservoir including limnology is provided by Stockner at al (2001). Although factors influencing productivity and related fish resources are well described, there was a lack of basic mapping such as bathymetry required to assess fish abundance. The state of mapping was evident from the number of different surface area estimates available in printed reports. Full pool area estimates for Williston Reservoir range from 1,647 km^2 to approximately 1,800 km^2 and no bathymetric mapping was available prior to this survey (Table 1). Since fish population estimates are derived by extrapolating fish density to reservoir area at depth, the reliability depends largely on the accuracy of area estimates. This is especially important in reservoirs when comparing results from different surveys since water levels and therefore habitat areas often change considerably between surveys.

Table 1. Williston Reservoir surface area estimates and source.

Source	Surface area estimate (ha)
MSRM 1:50,000 TRIM mapping, 2000	164,769
Balkwill, 1991 (Fisheries Technical Circular No. 90)	165,800
Bruce and Starr, 1985	173,588
BC Hydro records 1988	177,870
BC Hydro PWFWCP website 2003	~180,000

In order to conduct a reconnaissance level inventory of the fish resources in Williston, a rudimentary bathymetric map was required. The only sources of information available

were pre-impoundment topographic mapping at a scale of 1:20,000 (showing 20ft contours) and several echograms (showing cross-sectional images) from the 1988 acoustic survey. The topographic map images were obtained in electronic format from BC Hydro.

METHODS

Mapping

Assembling Bathymetric Information

A total of 57 electronic image files supplied by BC Hydro of pre-impoundment 1:20,000 scale topographic maps were merged to form a single image map of the entire reservoir. The image was then scaled and positioned until the 2,200 ft contour line (i.e., full pool elevation) best fit the most recent reservoir outline available from the provincial Terrain Resource Information Mapping (TRIM database). This enabled proper positioning of mapping coordinates (i.e., latitudes and longitudes) to the map image. The original river channel was highlighted to indicate the deepest part of the channel for navigation and every third contour below the full pool outline was highlighted to approximate 20m depth contours. The resulting map was printed at a scale of 1:50,000 and used for navigation in the field and for estimating sample areas by depth stratum for the acoustic survey. Echograms produced by Biosonics in 1988 were scaled and located on the map in order to verify the general topography and check for unforeseen hazards such as standing timber not evident from contour mapping. This was particularly useful for locating safe sites for trawling. Copies of the bathymetric map were further reduced to a 1:100,000 scale (10 map sheets in total) and included as a separate appendix to this report along with echograms from the 1988 and 2000 acoustic surveys (see Volume 2 Appendices 8-10).

Calculation of habitat areas by transect zone and depth

Habitat areas for the Williston Reservoir were estimated from the composite map constructed from 1:20,000 pre-impoundment topographic maps described above. The reservoir was divided into a total of 41 different habitat zones: 32 acoustic transects and an additional 9 zones to cover un-sampled habitat in arms and bays (Appendix 1a). Ozi-Explorer geographic mapping software was used to measure zone areas at the surface and at the 20m contour. Zone areas at the 40m and 60m contours were computed manually as a proportion of the 20m strata area by comparing average widths across the contour intervals to average width across the 20m contour interval. Habitat areas for each zone by one meter depth intervals were interpolated from the surface, 20, 40 and 60m zone areas using a linear relation and entered into a matrix of transect area by depth (Appendix 1b). The resulting matrix will enable comparison of future surveys conducted at varying pool elevations (Appendix 1b).

The habitat area by depth matrix in Appendix 1b was used to determine the surface area at the time of survey in August 2000 (i.e. elevation of 667m) and the area at the midpoints of each 5 meter depth stratum used in expanding acoustic densities. Reach areas used for extrapolating fish densities are presented in Appendix 1c.

Hydroacoustic sampling

Night-time collections of hydroacoustic data in pelagic habitats were collected during August 26-31, 2000 concurrent with trawl and gill-net sampling. The survey consisted of 29 standard transects, 19 in the main basin (Parsnip & Finlay reaches) and 10 in the Peace Arm. Three transects of the original 32 zone estimate were not completed due to time and weather constraints. Transect locations coincided with every second location surveyed in 1988 where depths were greater than 20 meters at low pool.

Acoustic survey data were collected using Simrad models EY200P 70 KHz single beam and EY500 120 KHz splitbeam systems. Transducers were towed on planers alongside the boat at a depth of 1.5 m and data were collected continuously along survey lines at 1-2 pings·s^{-1} while cruising at 2m·s^{-1}. Data from both systems were collected and stored on PC computers which provided preliminary data analysis and target verification between systems. Data from the two echosounders was backed-up on Sony Digital Audio Tape (DAT) and portable Backpack CD Writer. The Simrad systems were calibrated in the field at the beginning of the survey in the Peace Arm at the Portage Mountain Marina and specifications and field settings are shown in Appendix 2a. Field calibrations were conducted by collecting target strength data from copper spheres suspended in the center of the echosounder beam at 10-15 m from the transducer. Adjustments were made so that received signals correspond to the empirical strength of the spheres at 70 and 120 KHz. Navigation was by radar, GPS, 1988 acoustic transect echograms and a compilation of pre-impoundment 1:20,000 topographic and 1:50,000 NTS mapping.

The 70 KHz Simrad survey data were digitized and analysed using the Hydroacoustic Data Acquisition System (HADAS) program version 3.98 by Lindem (1991). The HADAS statistical analysis performed a function similar to manual counting to determine the number of targets per unit area by depth stratum. The HADAS statistical analysis performed a function similar to manual counting to determine the number of targets per unit area by depth stratum. Habitat was stratified by 5 meter depth layers and then further stratified into relatively homogeneous zones within each basin. Regression through origin of echo counts on areas sampled produced mean density and standard error values for each stratum used to develop abundance estimates. In addition, the HADAS estimated the fish size distribution using a statistical deconvolution based on Craig and Forbes (1969). The 70 KHz fish density (fish·ha^{-1}) and target strength decibel (dB) outputs were compiled into Excel worksheets for further post processing of the data. Habitat areas were aligned with transect data for computation of maximum

likelihood estimates (MLE) and bounds of the pelagic population, using a Monte Carlo simulation procedure with 30,000 iterations per run.

The 120 kHz split beam data was analysed using the Echo-signal Processing program (EP53) version 5.4 by Lindem (1999). The 120 KHz data were used as a secondary measure of fish density to the 70 KHz data and to conduct target strength (TS) analysis. Split-beam target strength measurements are received on four separate transducer lobes, which enable triangulation of targets within the beam and measurement of individual echoes. Fork lengths of trawl and gillnet caught fish were converted to an equivalent decibel (dB) scale using Love's (1977) empirical relation and compared to acoustic size distributions. The relation of acoustic target strength and fish size according to Love (1977) is shown in Appendix 2b.

Population estimates were extrapolated only to pelagic habitat area since all sampling in August 2000 was done in deep water. To enable direct comparisons to be made, the Biosonics 1988 acoustic estimates were re-calculated based on standardized areas of pelagic habitat at depth.

Trawl Sampling

A standard trawl survey of the pelagic habitat (>20 depth) in the Williston Reservoir was conducted concurrently with the acoustic survey. The survey design and sampling techniques were similar to kokanee stock monitoring that has been conducted on southern BC lakes since 1989 (Sebastian et al. 1995b). This trawl technique used a relatively constant boat speed and the depth of the trawl net is controlled by the amount of cable deployed. Although this works well at depths of 10 to 50m, there can be problems sampling near the surface. Above 10 meters depth the cable is fairly short and the net tends to "float" up and precise depth of sampling is difficult to control.

The survey design consisted of six stations with three replicate trawls per station for a total of 18 trawls, however, only one replicate was completed at station 6, and two were completed at station 3 (due to sampling conditions) for a total of 15 trawls. Three trawl stations were situated on the Peace Reach and one station on each of the Junction, Finlay and Parsnip reaches. Stepped-oblique trawls were used to sample representative volumes of water at all depths. The net was fished for 15 minutes over six consecutive depth layers which sampled from 30m depth to the surface. The trawl net used was a 15m long beam trawl with a 5m by 5m square opening towed at $0.8 m \cdot s^{-1}$. The net consisted of graduated mesh panels from 10cm (stretched mesh) at the head bar to 0.6cm at the cod end. Net depths were estimated from the cable angle and the length of cable deployed. A global positioning system (GPS) was used to determine distances travelled and resulting trawl sample volumes.

Captured fish were kept on ice until processed the following morning. The species, fork length, weight, stage of maturity were recorded. Scale samples were collected from all fish for age interpretation. A representative sub-sample was preserved in 10% formalin

for long-term storage. The trawl and gillnet data together provided species and size information that was used for interpretation of acoustic target strength (TS) distributions.

Gill net sampling

Gillnet data used in this report was collected August 2000 by PWFWCP staff concurrent with trawl and acoustic surveys and was reported by Pillipow and Langston (2002).

RESULTS AND DISCUSSION

Water level and survey conditions

Trawl and acoustic surveys were conducted at night-time from August 26 to 31, 2000, during the new-moon period. The reservoir surface elevation at the time of survey was at 666.3m or 5.7 meters below full pool. This was similar to the pool elevation of 667m reported during the September 1988 acoustic survey. Water temperature profiles available for mid-August and early September showed that the reservoir was strongly stratified with a distinct thermocline found at depths of 20-30m and down to 35m near the dam (Appendix 3). Temperatures in August were 15-17°C at the surface and only 5°C below the thermocline (Appendix 3). At the time of the survey, the weather was changing from a period of summer calm to windy and cooler fall conditions. By the end of the first week of September surface temperatures had declined to 10°C at most stations. Unfortunately, vertical temperature profiles were not done at the time of the survey but conditions were likely more similar to September than to August temperatures. Despite unsettled weather conditions, hydroacoustic data was successfully collected from all reaches. Except for the third trawl at station 3 (that was cancelled due to strong winds), trawl sampling was completed at all five stations and one additional tow was done opportunistically on the Peace Reach at a sixth station in vicinity of Carbon Creek (Fig.1).

Habitat area

The full pool surface area used in this report was 164,430 ha and was based on most recent TRIM shoreline mapping available from Inventory and Data Systems Branch of the Ministry of Environment (now Ministry of Sustainable Resource Management) (Table 1). Reservoir surface areas at the time of survey were estimated at 81-87% of the full pool surface area for the shallower north-south oriented reaches and 98% in the steep-sided Peace Reach (Table 2). The total area of pelagic or deep water habitat (>20m depth) was estimated at 141,800 ha or 57% of reservoir surface area at the time of survey.

Table 2. Williston Reservoir habitat area estimates by reach based on Appendix 1b.

Parameter/elevation	Surface areas (ha)				
	Parsnip	Junction	Finlay	Peace	Total
Surface area at full pool (672m)	18,483	37,907	76,698	31,345	164,430
Surface area at time of survey (667m)	15,044	33,002	62,843	30,903	141,792
% of full pool area	81%	87%	82%	98%	86%
Pelagic area at time of survey (647m)	3,368	20,396	28,595	27,799	80,158
% of surface area at survey time	22%	62%	46%	90%	57%

Pelagic habitat area ranged from 22-46% of surface area in the Parsnip and Finlay reaches compared with 62-90% in the deeper Junction and Peace reaches (Table 2). Both Parsnip and Finlay reaches therefore had significant areas of near-shore (<20m) habitat which was not sampled during this investigation. Some speculation of potential fish numbers in this habitat is presented in the species composition section.

Acoustic Survey

Fish Density Distributions

Fish density distributions and abundance estimates were based on hydroacoustic surveys of pelagic habitat (i.e. >20m depth) only. Fish that were associated closely with the bottom or within treed areas were not included in the analysis, but were not considered to be significant at the time of this survey. Fish density at individual transects ranged from 28 to 219 fish·ha^{-1}. Figure 2 shows the distribution of fish density estimates over the length of the reservoir. Average densities by reach for the Finlay, Parsnip, Peace and the Junction reaches were 139, 101, 70 and 44 fish·ha^{-1} respectively. Finlay Reach had highest densities with a range of 59-219 fish·ha^{-1}. Lowest average densities were found in the Junction Reach (range: 28-67 fish·ha^{-1}) and in the vicinity of Carbon Creek (range: 17-28 fish·ha^{-1}) in the lower half of the Peace Reach (Fig. 2).

Variability between transect densities may be due to local habitat conditions including nutrient inflow, depth, exposure, proximity to shoals and influence of submerged timber, or may be a result of proximity to recruitment sites. The variability of densities observed in Williston Reservoir (i.e., an order of magnitude) was fairly typical for large reservoirs as evident on Arrow, Revelstoke and Kinbasket reservoirs (Sebastian et al. 2000; Sebastian et al 1995a). The highest densities tended to be near the upstream end of Finlay, Peace and Parsnip reaches indicating that it may likely be nutrient related.

The original study design included only three reaches: Parsnip, Finlay and Peace based on earlier studies. However, upon review of fish distributions in Figures 2 and 4a, it became obvious that the north half of the Parsnip Reach was more similar to the Peace

Reach in terms of fish density and vertical distribution and maximum depth. This section will be referred to as the Junction Reach for purposes of reporting fish density and abundance in this report.

Low overall fish densities in Williston suggest that the reservoir is bordering on ultra-oligotrophic and are consistent with recent limnological studies reported by Stockner et al (2001). Average transect densities in the vicinity of the limnological stations appeared to be roughly correlated with estimates of daily primary production (Fig. 3). In order to facilitate reach comparisons with limnological data, the Peace Reach was divided into upper and lower sections which coincided with natural changes in reservoir morphometry and observed differences in fish density (i.e. the lower half of Peace Reach is wider, deeper and has lower average fish density).

Vertical Distribution

The vertical distribution of fish can have an effect on the reliability of acoustic fish counting results since fish at depths of less than 5 meters are difficult to enumerate with a towed "downward looking" transducer. Within 5 meters of the transducer, the viewing area is very limited and the number of fish echoes sampled is often too small to be statistically valid. At distances (i.e. depths) of less than 2.5 meters echo-counting is not possible. For kokanee monitoring in southern BC, this is generally not a problem since kokanee typically reside below the thermocline at night during summer and fall (seeking cooler water), and are normally found at depths of 15m or more. The August survey timing was chosen in Williston as the most likely time to find thermal stratification. It was anticipated that problems might arise from fish being too deep and hidden among submerged timber rather than being too shallow to enumerate effectively.

In Williston Reservoir, vertical density distributions showed that fish ranged from the minimum possible survey depth of 2.5m to approximately 35m depth (Fig. 4a). Concentrations of fish within 10m of the surface were very evident in the shallow Finlay and Parsnip reaches and it can be assumed that they extended to the surface in these areas. Fish were found to be deeper and spread over a wider range of depths in the Junction and Peace reaches and it is unlikely that there were many in the top 2.5m (not sampled). Estimates of fish density and abundance are therefore considered to be very conservative for the Finlay and Parsnip reaches as they do not include fish above 2.5m of depth.

A 2.5-5.0m depth stratum was added to the acoustic analyses after it was discovered that significant numbers of fish were near the surface (i.e., in 5-10m layer) in two of the four reaches. It is worth noting that fish concentrations near the surface were not evident from the echograms at the time of survey and were not appreciated until layered analyses were completed after the survey. A review and 3-dimensional plot of Johnson and Yesaki's (1989) acoustic data also showed that fish were concentrated near the surface in 1988, although this was not discussed in the report (Fig. 4b). Densities reported in 1988 surveys are therefore also conservative as some fish near the surface were likely missed. Note that 6m depth strata were used in the Biosonics survey and

the majority of fish in all reaches were found in the upper 3 depth strata or within 18m of the surface.

Water Temperature and Fish Distribution

Water temperature can be used to determine probable distributions of some fish species such as kokanee due to their relatively narrow range of preferred temperatures (i.e. 6-13°C). Whitefish have a much wider range of tolerance for temperatures (0 - 26°C) and an optimum for growth of 8-14°C (Ford et al. 1995). Temperature profiles from August 9-13, 2000 suggest a relatively narrow range of depths (18-30m) had preferred temperatures for kokanee, while the upper 18m were near the optimal range for whitefish at approximately 15-17°C (Appendix 3). By early September, the surface temperatures had declined to 10-12°C and were optimal for both species (Appendix 3). Based on the apparent proximity of fish including kokanee to the surface, it appears that temperatures at the time of survey were more similar to the September profiles. It also appears that our sampling just missed the warmest summer period when some segregation of kokanee and whitefish may have occurred. It is recommended that further investigations be done earlier in the summer to take advantage of any potential for species segregation by temperatures (first two weeks of August). It is also recommended that temperature profiles be done concurrent with any further pelagic fish sampling or hydroacoustic work.

Temperatures below 30-35m depth were only 5°C and help to explain the lack of fish observed on the echosounder in deep water. Given the relatively short growing season in Williston Reservoir it may be advantageous for pelagic fish to spend longer periods of time feeding in the warmer surface waters in order to optimize growth.

Fish Abundance and reliability (all species combined)

The maximum likelihood abundance estimate (MLE) for combined species in pelagic habitat of Williston Reservoir was 5.92 million (5.07 to 6.88 million) (Appendix 5). The distribution was 4% in Parsnip Reach, 9% in Junction Reach, 63% in Finlay and 24% in the Peace Reach (Table 3). This estimate is considered conservative as it applies to the pelagic habitat only and does not include the extensive areas of habitat less than 20m deep which is known to support fish based on previous gillnet sampling results of Blackman (1992) and Barrett and Halsey (1985).

The vertical distributions of fish in both Parsnip and Finlay reaches showed increasing fish abundance with decreasing depth (Fig. 5), suggesting highest fish densities may have been in the uppermost layer (i.e. surface to 2.5m depth), which could not be sampled with a downward looking transducer. Extrapolating the proportions by depth to the surface would suggest an additional 50-60% or 2 million fish for the 0.0-2.5m depth stratum on Finlay Reach (Fig. 5). This "adjustment" is significant as it increases the total reservoir population estimate by 1/3 to approximately 8 million fish (from 5.9 million).

Table 3. Fish abundance estimates by reach and depth stratum for pelagic habitat of Williston Reservoir based on August 2000 acoustic survey.

Stratum	*Estimated numbers of fish (all species) in pelagic habitat*									
Depth (m)	**Parsnip**	**%**	**Junction**	**%**	**Finlay**	**%**	**Peace**	**%**	**Total**	**%**
2.5 - 5	80,800	34	0	0	1,674,500	45	0	0	1,755,300	30
5 - 10	88,200	37	27,500	5	644,300	17	215,300	15	975,300	16
10 - 15	45,800	19	167,900	32	466,100	12	226,200	16	906,000	15
15 - 20	19,500	8	109,700	21	280,000	7	213,100	15	622,300	11
25 - 30	4,300	2	200,000	38	323,200	9	294,900	21	822,400	14
30 - 35	0	0	27,300	5	285,500	8	442,600	31	755,400	13
35 - 40	0	0		0	65,500	2	18,800	1	84,300	1
Total	238,600	100	532,400	100	3,739,100	100	1,410,900	100	5,921,000	100
% of tot.	4%		9%		63%		23%		100%	

The same approach would suggest an additional 30% or only 70,000 fish may have been missed on the surface of the Parsnip Reach (Fig. 5). This, however, was insignificant at only 1.2% of total reservoir numbers for pelagic habitat. The abundance estimates of nearly 2 million fish for the Peace and Junction reaches are thought to be fairly reliable as there was little evidence of fish being aggregated near the surface or the bottom where they would be difficult to quantify (Fig. 5). A best estimate of total fish abundance for Williston Reservoir pelagic habitat was 8 million fish assuming that Finlay may have been under estimated by 2 million fish.

A further caution worth noting for the Finlay Reach abundance estimate is that estimates too near the transducer may be unreliable due to small sample sizes of fish echoes detected and of the "viewing" areas used to calculate and extrapolate densities. In practical terms this means the estimate of 1.7 million or 46% of the Finlay estimate at 2.5-5m depth was based on less than 5% of the total fish echoes detected. This is normally not a problem in southern surveys since fish such as kokanee are not found near the surface at night. It appears that a different strategy is required to accurately assess fish abundance in Williston Reservoir where they are at or near the surface.

A possible solution to this problem would be sub-sampling with a towable upward looking transducer which could be submersed to depths of 15-20 meters and view fish towards the surface. Some research and development would be needed to find a suitable towed body from which an upward looking transducer could be deployed. Concerns in Williston would be twofold – first to get a design which could be controlled at a fixed depth and towed at a reasonable speed without "rocking" or planning upward in rough water. The second consideration is that it be easily deployable and retrievable in rough water as it will be stored on deck while running between transects. This technique would be combined with some modifications to trawl gear enabling better quantitative assessment of surface habitat which would be done concurrently (see section on trawling)

Comparison of 2000 and 1988 acoustic surveys

Johnson and Yesaki (1989) estimated total fish abundance in the Williston Reservoir at 11.2 million (7.8-14.5 million) in September 1988 by expanding a partial estimate by the proportion of habitat area not sampled. This estimate was not however directly comparable to the August 2000 estimate as different habitat areas were used. The surface area estimate used in the 1988 survey appeared to be within 3% of our estimate but some of the stratum areas at depths below surface were up to 40% higher and may have been derived from individual transects rather than bathymetric mapping. It appears fish abundance estimates above the 20m depth were extrapolated to total reservoir habitat area at each depth rather than just to the area of pelagic habitat that was sampled. Since habitat areas should have been similar at similar reservoir levels, the 1988 abundance estimates were re-calculated by applying average reach densities by depth strata to our areas estimates for the same reaches and strata depths. The resulting abundance estimate for pelagic habitat only in 1988 was 5.8 million or nearly identical to the 2000 estimate. Both estimates must be considered highly conservative as they both missed fish near the surface. In fact, the vertical distributions suggest that the 1988 survey likely missed more fish and in more areas than the 2000 survey. Therefore it is likely that the pelagic population in 1988 was larger than in 2000. It also provided evidence that September surveys may be too late in the season to take any advantage of thermal stratification and higher surface temperatures, which may have improved the accuracy of hydroacoustic surveys.

Although acoustic abundance estimates were similar between 1988 and 2000 surveys the distribition of fish was different. In 1988 the Junction Reach had by far the largest proportion of total fish compared with the Finlay Reach in 2000 (Table 4). Numbers of fish in the Parsnip and Peace reaches appeared to be similar between surveys.

Table 4. Comparison of 1988 and 2000 acoustic abundance estimates and average densities by reach for Williston Reservoir.

Reach	BC Fisheries August 2000		Biosonics September 1988	
	(no.)	(no/ha)[1]	(no.)	(no/ha)[1]
Parsnip	239,000	73	366,000	109
Junction	532,000	26	2,350,000	115
Finlay	3,739,000	133	1,423,000	50
Peace	1,410,000	52	1,659,000	60
Total	5,920,000	75	5,798,000	72

1. Note these are weighted average densities derived from reach populations (and are not equal to the average of individual transect densities)

Trawl Sampling

Mid-water trawl sampling was intended to quantitatively sample fish that occupy mid-water habitat between 5 and 50m depth at night. Since very few fish were observed on

the echosounder below 35 meters, the trawl sampling was targeted on depths from 35m up to 5m below the surface or 6 consecutive strata of 5 meters each.

A total of 15 trawls were completed at 6 different stations, three on the Peace, and one on each of the Junction, Parsnip and Finlay reaches (Fig. 1). Only two of the three trawls planned for Finlay Reach were completed due to deteriorating weather. Trawl station #6 was an additional sampling location done opportunistically when returning from the Clearwater (station 5). Only a single trawl was conducted at this station before dawn. Trawl sampling logs and catch data are shown in Appendix 6a and UTM coordinates for sampling are shown by Appendix 6b.

Each trawl was 90 minutes in duration or 15 minutes for each 5m depth layer. Average boat speed ranged from 0.48-0.88 $m \cdot sec^{-1}$ resulting in total distances trawled of 2.6-4.5km and sampled volumes of 65,000 - 112,500m^3 (of water filtered) per trawl. When consecutive layers were "stacked" the equivalent surface area sampled ranged from 0.22 - 0.38 hectares per trawl (Table 5). The one exception was a single "surface" trawl for 30 minutes at station 5 which sampled 0.79ha in which no fish were captured. Ironically, if surface trawling had been done at either Finlay or Parsnip stations where fish were aggregated near the surface, the result would likely have been different. As mentioned previously, aggregations of fish near the surface in Finlay and Parsnip reaches were not evident until acoustic data was processed.

Table 5. Summary of trawl sample sites, locations, area sampled and catch per unit effort (CPUE).

Station	No of trawls	Depth (m)	layers (no.)	Duration (min/trl)	Dist.[1] (km)	Volume (M^3x1000)	Area[2] (ha)	Catch (no.)	CPUE (No/ha)
1. Parsnip	3	5-35	6	90	10.44	261	0.87	6	6.9
2. Junction	3	5-35	6	90	12.33	308	1.03	16	15.6
3. Finlay	2	5-35	6	90	7.08	177	0.59	6	10.2
4. Peace Clearwt	3	5-35	6	90	12.90	322	1.07	7	6.5
5. Peace Forebay	2	5-35	6	90	8.08	202	0.67	0	0.0
Forebay	1	0 - 5	1	30	1.58	40	0.79	0	0.0
6. Peace Carbon	1	5-35	1	90	3.77	94	0.31	2	6.4

1. Distance, volume and catch is cumulated by station
2. Area is for single depth layer (layers are stacked) and cumulated for station

Trawl catch rates were extremely low in Williston Reservoir and a total of only 37 fish were captured in 15 trawls. Excluding the forebay station where no fish were caught, the trawl catch per unit effort (CPUE) ranged from 6-15 $fish \cdot ha^{-1}$ (Table 5), which by southern BC standards would suggest actual fish densities in the order of 30 to 75 $fish \cdot ha^{-1}$ (i.e., assuming 20% efficiency of the net). It appears that fish densities in Williston were below the threshold at which trawl CPUE and acoustic densities show a linear relationship. In southern systems, this threshold for kokanee density is about 100-200 $fish \cdot ha^{-1}$ but can vary depending on how aggregated or dispersed the fish are. Below this threshold the catch efficiency compared to acoustic densities declines below 20% and considerably more trawl effort is required to maintain statistically valid catch

numbers. This can be partly offset by increasing trawl effort to maintain viable sample sizes, however at some point increasing costs become limiting. Acoustic surveys showed that fish at the Forebay station were more widely dispersed (i.e. 5 to nearly 40m depth) than at other locations which might explain why trawling did not capture any fish at this location.

Another reason for low catch numbers on Williston may have been the white mesh used on some of the panels of the trawl net (Don Miller – Trawl contractor, Kootenay Wildlife Services pers. com.). A standard trawl net (typically of black or dark green mesh) was ordered but mesh color was not specified. The mistake was noted too late to allow for a change. Trawling is done at night to minimize the avoidance and white mesh may have enabled fish to see the net approaching. It is recommended that the white panels be replaced prior to any further trawling.

The following species were captured by trawl net: lake whitefish, kokanee, peamouth chub (*Mylocheilus caurinus*), lake trout (*Salvelinus namaycush*) and slimy sculpin (*Cottus cognatus*). Lake trout were only captured by trawl and not gillnet presumably as they prefer deep water and cold temperature. Sculpins are usually benthic and not normally captured by trawling unless sampling too near the bottom or near shoal habitat. Trawl catches were too low to compare densities and species by station, so could only be considered in total. In the absence of other information, trawling indicated that the two main species occupying mid-water habitat at night were lake whitefish and kokanee suggesting whitefish were only slightly more abundant than kokanee. Other species were considerably lower in abundance or were able to avoid being captured in the trawl net (Table 6). The larger size of whitefish may make them less vulnerable to capture in the trawl than kokanee so their relative abundance in mid-water habitat may have been underestimated.

Table 6. Summary of trawl catches by species and sampling location for Williston Reservoir, August 2000.

Trawl		Number of fish captured by species							
Reach	**Station**	**BT**	**CC**	**KO**	**LT**	**LW**	**PCC**	**RB**	**Total**
Parsnip	1. Blackwater R			4		2			6
Junction	2. Junction		1	6	1	7	1		16
Finlay	3.Teare Cr.			1		5			6
Peace	4. Clearwater			3		4			7
Peace	5. Forebay			2					2
Peace	6. Carbon Cr.								
Totals			1	16	1	18	1		37

Suggested modifications to trawl procedures

Sampling above 10m depth with a standard kokanee trawl net can be difficult as the net tends to float (due to the short cable length) and the depth is difficult to control. There may also be some avoidance of the boat when trawling on the surface near the boat.

Some minor modifications to trawl gear and sampling design could improve sampling efficiency near the surface for applications such as Finlay Reach. Installation of large floats on the head-bar could be used to control net depth. With floats on the net, the boat avoidance issue could be eliminated by letting out more cable and trawling in an arc. The sampling design would be changed to a combination of layered oblique for deeper layers (14 to 35 m depth) and layered hauls on the surface and 7 m using floats for the upper two layers. Some experimentation with different float arrangements, cable lengths and boat speeds would be required to maximize catch efficiency. To increase catches in the oblique trawls, either a larger net can be towed or the duration of netting can be increased from 15 to 30 minutes per layer. With a 7m high net (instead of the 5x5m), each oblique trawl would require 3 layers of 30-45 minutes each for 90-135 minutes each and then two additional layers would be done using floats to trawl at 0-7m for 30 minutes and 7-14m for 30 minutes. This would add significantly to the total time trawling at each station, but should increase catches, especially on the surface in Finlay Reach. The advantage over gillnetting is that data would be more useful for making quantitative comparisons between species and could be used to assist in determining the relative vulnerability of kokanee and whitefish to gillnets.

Gillnet Sampling

The following species were captured in pelagic floating gillnets during August 2000: lake whitefish, peamouth chub, kokanee, rainbow trout and bull trout (Table 7). Both species and relative numbers of fish caught in gill nets were considerably different than that suggested by the trawl, however, caution must be taken to keep this information in context. Compared with trawling, gillnets caught larger numbers of fish, larger sized fish and suggested a different "mix" of species. Gillnets targeted more heavily on fish in the vicinity of the surface compared with fish that vertically migrate and only come to the surface to feed (e.g., kokanee). Pillapow and Langston (2001) caught a total of 679 fish from seven stations on the reservoir. The main species in order of decreasing abundance were lake whitefish, peamouth chub, rainbow, kokanee and bull trout.

Table 7. Summary of gill net catches by species and sampling location for Williston Reservoir during August 2000 from Pillipow and Langston (2002).

Gillnet		Number of fish captured by species							
Reach	**Station**	**BT**	**CC**	**KO**	**LT**	**LW**	**PCC**	**RB**	**Total**
Parsnip	Heather Point	3		2		10	13	4	32
Parsnip	1. Blackwater	0		4		7	1	58	70
Junction	2. Junction	2		12		64	28	21	127
Finlay	3. Teare Cr.	2		7		114	7	3	133
Finlay	Factor Ross	2		7		56	8	6	79
Peace	4. Clearwater	1		5		4	6	9	22
Peace	5. Forebay	1		13		53	126	23	216
Totals		11		50		305	189	124	679
CPUE (number $100m^{-2}h^{-1}$)		0.01		0.05		0.30	0.17	0.12	1.32

Comparison of netting methods and bias

One of the objectives of the Williston study was to see if comparisons could be made between different methods of capturing fish (i.e., trawling and gillnetting) and to determine if the results could be used in a complimentary way to assess fish resources in pelagic habitat. There have been no previous attempts to quantitatively compare surface gillnetting to mid-water trawling, so no standards or guidelines exist on how this might be done. The first focus was on how to interpret gillnet data given the number of variables. Difficulties in interpreting gillnet results involved identifying the biases, since catches are dependent on net size, mesh size, depth of set, depth of water, time of day, location, duration of set and especially differences in the species targeted. Commercial fisheries have developed net standards and methods to specifically take advantage of gillnet bias to target certain species and sizes of fish. By contrast, the objective of Provincial fisheries assessments has been to minimize species and size biases through a combination of standarized mesh sizes and replicate sampling. Quantitative comparisons should be made between similar net sets and within species in order to limit the number of variables so that differences can be attributed to fish abundance. Comparing catches between species is especially difficult and subjective, because of differences in vulnerability (to catch) between species. For example, piscivorous fish such as rainbow and bull trout have much greater cruising distances than plantivores, so have an increased likelihood of encountering a net (Rudstam et al. 1984). Predators may also be attracted to gillnets by movement of fish already captured. The higher catches rates for rainbow compared to kokanee in August 2000 gillnets, therefore, do not reflect a high relative abundance, but rather their higher vulnerability to capture.

It was concluded that direct and quantitative comparisons would be too difficult. Consequently, it was decided that the best use of historic and current gillnet information was to summarize catches by species and the type of net sets used (i.e., near-shore versus offshore, surface versus submerged sets). This would allow generalizations to be made on apparent species distributions in Williston Reservoir considering their relative vulnerability to gillnets.

The diagram below illustrates the various net types and locations fished in order to help visualize differences between gillnet methods used in the 1974, 1988 and 2000 gillnet surveys. Note that nets used in 1975 were deeper (i.e., 7.5m) than the standard 2.4m deep nets used in more recent studies, and more combinations of floating and sinking nets were fished near shore in 1975. An important difference in pelagic netting was that Blackman (1992) fished 5m below the surface while investigators in 1975 and 2000 fished at the surface in pelagic habitat. Refer to footnotes of Tables 8, 9 and 10 for specific net dimensions. Ironically, the differences in methods between the three surveys provided valuable information on apparent habitat preferences of the different species.

Catch information from Barrett and Halsey (1985), Blackman (1992) and Pillapow and Langston (2002) were summarized and compared in Tables 8, 9 and 10. There may be some inaccuracies as these summaries were re-constructed largely from other summary tables in the absence of raw data.

Species distribution and vulnerability to capture

The following observations and generalizations were made for key species by comparing summary catches from the three gillnet surveys on Williston Reservoir.

Lake Whitefish

Results from the 1974 study showed clearly that lake whitefish preferred near-surface habitat and were found in similar numbers in surface sets both near shore and off-shore (Table 8). Nets set below 7.5m got fewer fish. Blackman (1992) found whitefish everywhere in near shore nets and slightly lower numbers in the pelagic set (Table 9). This was consistent with their preference for occupying shallow water even when off shore. Blackman's pelagic nets may have got lower catches than the near-shore nets since a proportion of the targeted fishing area was likely too deep for whitefish at 5-20.2m below the surface. All three investigations indicated that lake whitefish were the most abundant species found in pelagic habitat (Table 10).

Peamouth chub

Peamouth chub are considered to be mainly insectivorous that feed on a wide variety of aquatic insects and their larvae and some terrestrial insects (Clemens 1939), and also consume planktonic crustaceans (Scott and Crossman 1973). They are known to travel in schools and are often the most numerous fish found in shallow weedy zones of lakes (Carl et al. 1977). Barrett and Halsey (1985) results were consistent with the literature as they found highest numbers to be near shore and associated with the bottom (Table

8). Very few chub were captured in pelagic nets on the surface. Blackman found the same strong preference for near shore and bottom habitat for this species and found very few in open water (Table 9). Compared with previous pelagic sets, Pillipow and Langston (2002) caught very high numbers of peamouth in open water (Table 10). However, catches between sites were highly variable (67% of total numbers were caught at one station) suggesting they are patchy or travelling in schools. Total numbers of peamouth in 2000 were likely much lower than the total catch would suggest, and may be more in proportion to low numbers caught at 5 of the 7 stations (Table 7). As primarily insectivores, they will likely remain near the surface in open water and therefore be highly vulnerable to capture with surface gillnet sets. Trawling confirms very low numbers below 5 meter depth and they are not considered to be a significant species in terms of their abundance in pelagic habitat.

Table 8. Summary of 1975 gillnet catches by species and net type from Barrett and Halsey (1985)

Net type	Bottom depth (m)	Fishing depth (m)	LW	PCC	RB	KO	BT	Other	Total
Pelagic	40 - 160	0 - 7.5	1019	27	84	1	38	294	1464
Floating	30	0 - 7.5	884	78	119	2	54	505	1641
Floating	15	0 - 7.5	997	57	132	2	60	497	1726
Floating	7.5	0 - 7.5	1054	135	113	2	62	614	1970
Sinking	30	23.5 - 30	94	164	22	0	10	423	713
Sinking	15	7.5 - 15	375	355	58	1	27	944	1760
Totals			4403	816	528	8	241	3277	9272

All nets were 7.5m deep and 91m long comprised of 6 panels of different sized mesh.

Table 9. Summary of 1988 gillnet catches by species and net type from Blackman (1992).

Net type	Bottom depth	Fishing depth	LW	PCC	RB	KO	BT	Other	Total
Pelagic	60m	5 - 20.2m	340	27	0	5	4	5	381
Floating	30m	0 - 2.4m	376	126	72	57	37	5	673
Sinking	15m	12.6 -15m	428	197	32	14	66	190	927
Sinking	7.5m	5.1 - 7.5m	490	480	24	2	93	310	1399
Totals			1634	830	128	78	200	510	3380

The pelagic net was 15.2m deep and 45.6m long; all other nets were 2.4m deep and 91m long.

Table 10. Comparison of catch by species in pelagic nets between the 1975, 1988 and 2000 gillnet surveys.

Year	Bottom depth	fishing depth	LW	PCC	RB	KO	BT	Other	Total
1975	40 - 160m	0 - 7.5m	1019	27	84	1	38	294	1464
1988	40 - 60m	5 - 20.2m	340	27	0	5	4	5	381
2000	40 - 160m	0 - 2.4m	305	189	124	50	11	0	679

Rainbow trout

Both Barrett and Halsey (1985) and Blackman (1992) found highest numbers of rainbow at the surface in the transition zone between near shore and off-shore habitat (i.e. at 30m). Rainbow were clearly found in close association with the surface by Barrett and Halsey and this was confirmed by the complete absence of rainbow in Blackman's pelagic net (set at 5-20m below surface) and mid-water trawl nets which sampled habitat between 5 and 35m depth. Being predators and confined to near surface habitat, they are expected to have the highest vulnerability to capture of any of the species in pelagic habitat. The moderate catch numbers are therefore not an indication of their abundance as much as their vulnerability to capture. Comparison of 1975 and 2000 catches might suggest that the abundance of rainbow has not changed, however it is difficult to make direct comparisons since the nets were different.

Kokanee

Kokanee are only vulnerable to gillnet capture when they are actively feeding on the surface. In southern lakes kokanee spend most of the day in deep water avoiding predation and in cooler water at night-time also away from the surface. If their behavior pattern is similar in Williston Reservoir, their vulnerability to capture is relatively low compared to species that spend more time on the surface. The 1974 study caught very few kokanee, but did indicate they were present in the reservoir (Table 8). In 1988, Blackman (1992) caught reasonable numbers on the surface in the transition zone and concluded they had increased since 1975 (Table 9). A near absence of kokanee in pelagic nets 5-20m below the surface provided some evidence they may have been concentrated near the surface, or at least were only vulnerable to gillnets on the surface. Comparing catches in 1974 and 2000 (i.e., both on surface) it appears there has been a significant increase in the numbers of kokanee in the reservoir.

The evidence of increased numbers of kokanee is not surprising given that more than 3.3 million fry have been released into Williston Reservoir tributaries since 1990. The fry were obtained either from Hill Creek or Meadow Creek spawning channels depending on their availability. Annual releases ranged from 250,000-450,000 fry over a period of eight years (1990-97). Spawner escapement observations also indicate that kokanee are on the increase. Although estimates in the early 1990's were spotty (Blackman, pers. Comm.; Peace Williston Compensation Program Senior Fish Biologist), the most recent spawner counts suggested about 80,000 spawners returned in 2002 (Appendix 7b). Interestingly, the majority of spawners were observed in streams entering Omineca Arm and were not found in great numbers in release streams.

Other species

The "other" fish species in Table 8 were largely comprised of mountain whitefish (*Prosopium williamsoni*), but also included some arctic grayling (*Thymallus arcticus*) which were most likely displaced riverine stocks following the flooding and formation of

the reservoir. It does not appear that these species have been reported in any significant abundance since 1975 and have likely been replaced by species more suited to reservoir conditions.

Species composition and population size.

Estimates of species composition presented here are highly speculative as they are based on a number of unproven assumptions and therefore should be considered "ballpark" at best. The first assumption is that combining all gillnet and trawl stations to look at general patterns of fish distribution in the reservoir can be roughly representative of the reservoir. Subjective estimates were made for the two key pelagic species: lake whitefish and kokanee. Two different estimates for kokanee were developed as follows:

1. The first approach assumed that the acoustic size distribution in Figure 14 can be used to determine an approximate proportion of age 0 sized fish in mid-water habitat and that the majority of fish this size in pelagic habitat were kokanee as indicated by limited trawl catches. Whitefish fry, if present would appear to be in a larger acoustic size bin according to limited trawl catches, so should not affect this estimate. The age 0 sized fish appeared to be in the order of 10% of the total acoustic fish numbers or about 600,000 to 800,000 depending on whether the additional 2 million in Finlay Reach are included or not. Assuming kokanee age 0 fish would comprise 60-75% of total kokanee numbers (Sebastian et al. 2000), the total kokanee population would be in the order of 800,000 to 1,300,000 fish. A kokanee population of this size (i.e. one million) would support a spawning escapement of approximately 40,000 to 90,000 fish. This is very similar to the most recent combined spawner counts for Williston tributaries of 80,000 estimated by PWFWCP staff in fall of 2002 (Appendix 7b.)

2. The second approach assumes that vulnerability of kokanee and whitefish are similar in surface gillnets. This assumption may be valid if larger kokanee (i.e. age 1+ and 2+ fish) spend considerable time near the surface feeding. Since the vulnerability of other species such as rainbow and peamouth is considerably higher than whitefish, their actual numbers in pelagic habitat are most likely less than 1 million and probably less than 0.5 million. Subtracting 0.5 million from the 2 million additional fish on the surface would leave a total of 6.0 to 7.5 million mixed kokanee and whitefish. Applying the gillnet proportions of (50/355)=14% kokanee or approximately 0.84 to 1.05 million fish. A ballpark estimate is again around 1 million kokanee. If it turns out the vulnerability of kokanee to capture is lower than for whitefish, then the kokanee population would be proportionally higher than 1 million fish. Some surface trawling may assist in answering the question of actual species composition and assist in better interpretation of gillnet catch data. This should be one of the objectives of future investigations.

The whitefish population in pelagic habitat can be estimated using the same approach as with kokanee in method 2. Assuming a population of 6.0-7.5 million mixed kokanee and whitefish as indicated above, the proportion of whitefish to the combined whitefish

and kokanee would be 86% and the pelagic population would be 5.2 to 6.5 million whitefish. At these population levels their average density in pelagic habitat would be 65-80 fish·ha^{-1}. Since whitefish showed similar gillnet CPUE near shore as off-shore, there may be an additional 4 to 5 million in the 61,600 ha of shallow habitat (<20m depth) around Williston Reservoir. The total population of lake whitefish in the reservoir may be in the order of 9 to 11 million. To verify current estimates for CPUE additional near shore gillnetting would be required.

Estimates for rainbow are difficult to develop from gillnet catches, and no trawling was done in immediate surface areas where rainbow might have been caught. Without some way to quantify their vulnerability to catch by gillnets, their abundance can only be inferred from other reservoirs where estimates have been made. Estimates of combined bull trout and rainbow trout all ages for Arrow Reservoir were 15,000 to 25,000 based on exploitation rates suggesting densities of only 0.5-1.0 fish·ha^{-1} (Sebastian et al. 2000). Acoustic densities of predator sized fish >32cm fork length suggested up to a maximum of 2.3 for both Arrow Reservoir and Kootenay Lake based on recent unpublished data (presented at Arrow Lakes Workshop, November, 2002). If pelagic habitat in Williston Reservoir is of comparable productivity for rainbow, the pelagic habitat may support in the order of 40,000 to 180,000 rainbow trout based on densities of 0.5 to 2.3 fish·ha^{-1}. It is unlikely that this number of fish would noticeably affect total fish abundance estimates for pelagic habitat at 2% or less of the total.

Age and Growth

Age interpretations and resulting size at age were determined only for the two main forage fish species in pelagic habitat: kokanee and lake whitefish. Ages for younger juvenile fish were estimated by observing modes on length frequency distributions. For trawl caught fish, scales were taken from most individuals and used to verify age estimates suggested by frequency analyses. For gillnet catches scales were taken from kokanee and otoliths were taken from whitefish and scale interpretations were contracted (Pillipow and Langston 2002). Some discrepancies in age interpretation were evident between trawl and gillnet catches.

Kokanee age and length-at-age

Three age groups were evident from combined kokanee trawl catches. Modes at 6,16 and 22cm corresponded to age 0, 1 and 2 kokanee, respectively (Fig. 7a). The mean length-at-age for trawl fish was 4.3, 15.9 and 22.2cm for age 0,1 and 2 fish, respectively (Table 11). Note that axis labels on the length frequency distributions refer to upper boundaries (i.e. 16cm includes fish from 15.1 to 16cm). When compared with trawl length frequency, the combined gill net catches also suggested three age groups, but with modes at 17, 23 and 29cm which most likely correspond to ages 1, 2 and 3 kokanee, respectively. Almost 90% of gillnet caught fish >24cm were reported to be mature and would have spawned during fall 2000. From these analyses it appears that the majority of kokanee spawned at age 3 in Williston Reservoir streams as in the majority of southern BC stocks.The presence of two non-mature age 3 fish may indicate

Table 11. Kokanee and lake whitefish size statistics from August 2000 trawl surveys.

Species	Station	age 0	age 1	age 2	age 3	age 4
Kokanee	Ave. length (mm)	43	159	222		
	Length range (mm)	34-52	143-166	220-223		
	Standard deviation	5.4	9.0	2.1		
	Sample size (n)	9	5	2		
Lake whitefish	Ave. length (mm)	79	157	210	249	271
	Length range (mm)	79	150-160		238-265	261-281
	Standard deviation	0.2	5.8		7.8	10.0
	Sample size (n)	2	3	1	9	3

the likelihood of a small component of age 4 spawners, which would likely be in excess of 30cm fork length at spawning time.

The length-at-age information derived through contract age interpretations for gillnet caught kokanee in 2000 were plotted and compared with trawl ages. Age interpretations clearly did not agree with our analyses, and suggested that kokanee live up to 6 years in Williston Reservoir (Fig. 8). Scale interpreters were however at a disadvantage by not having all age groups represented (i.e., no age 0 and few age 1) and did not have the benefit of a length frequency analysis to assist in aging. Our age interpretation for kokanee was supported by earlier estimates of kokanee length-at-age done by Blackman (1992) (Fig. 9). It is recommended that kokanee scales particularly from gillnet surveys in 2000 be re-assessed in order to determine if errors have been made.

Kokanee age structure in southern BC is typically comprised of 60-75% age 0 and 25-40% age 1-3 fish, with age 1 fish being the largest component of the 1-3 group. Although trawl catches were too low to estimate age proportions, the fry did comprise nearly 60% of total kokanee captured. The smaller numbers of age 1 kokanee in the gillnet sample likely indicated their lower vulnerability to capture by gillnet as a result of their smaller size.

Lake whitefish age and length-at-age

Trawl catches of whitefish were very low, however the combined length frequency distribution suggested at least 3 and possibly 4 ages with modes apparent at 7,15, (20) and 24cm presumed to be ages 0, 1 and 2 and 3, respectively (Fig. 7b). Scale analysis supported frequency age estimates and suggested a fifth age group at about 27cm, which appeared to be age 4 fish based on scale interpretation. The mean length-at-age for whitefish based on limited trawl samples and frequency analyses were 7.9, 15.7, 21.0, 24.9 and 27.1cm for age 0, 1, 2, 3 and 4 fish, respectively (Table 11). Overlaying the gillnet caught fish did not produce any clear modes on the length frequency that could be used for aging, but did show that the majority of fish were likely age 4 and older (Fig. 7b). In terms of proportion by age, there appeared to be an obvious lack of age 1 sized whitefish compared to older fish. Whether this is indicative of a typical

whitefish population structure, where several age classes exist beyond age 1, or whether it is due to decreasing efficiency of the gillnet to capture of smaller fish is not known. Until more information on age structure is available, it will be difficult to interpret gillnet data with respect to relative abundance of different aged fish.

Similar to kokanee there were discrepancies between scale age interpretation from trawl and length frequency analyses and the otolith age interpretations for gillnet caught fish in August 2000 (Fig. 10a). The otolith ages ranged from 2-10 years of age and showed no significant differences in fish size beyond age 4. Combined scale interpretation and length frequency analyses from trawl surveys in 2000 and gillnetting surveys in 1988 (Blackman, 1992) suggested very rapid growth of whitefish up to age 3 and a declining growth rate beyond this (Fig. 10b). Further age analyses are required in order to sort out differences between otolith and scale analyses and it is recommended that all samples be re-analyzed. It was evident that pelagic gillnets caught larger whitefish in 1988 (i.e., several >30cm fork length) than in 2000, so it appears that whitefish size may have declined over the past 12 years.

Acoustic Size Analysis

The split beam echosounding system was used at every alternate single beam site and produced comparable density estimates over the range of densities found throughout the reservoir. Regression analysis of the two data sets suggested that the data could be used interchangeably (Fig. 11). Low number of echo targets, particularly for size analysis of fish near the surface cannot be accurately proportioned using a single beam sounder and statistical algorithms as they depend on large sample sizes. Instead, the split beam echosounder data was used to estimate fish size distributions, as it calculates the size of each echo individually rather than relying on a statistical approach.

In order to compare size distributions of fish caught in the trawl and gillnet surveys with the size distributions suggested by the echosounder, it was necessary to convert actual fish lengths to their acoustic equivalent on a decibel (or logarithmic) scale. Love's (1977) empirical relation for dorsal aspect was used to make these conversions (Appendix 2b). The acoustic distributions from trawl and gillnet catches were very comparable for all but fry sized fish and showed up mainly in the -41 and –38dB size bins (Fig. 12). The occurrence of smaller "fry-sized" fish were evident in the -53dB size bin in trawl catches but were too small to be caught by gillnets. When trawl fish were separated by species, both kokanee and lake whitefish showed bimodal distributions indicating that age 0+ fish could be separated from older fish on this scale, however the modes for these two species appeared to be "out of phase" which might add to difficulties in separating fish into age groups in a mixed stock situation (Fig. 13). The mode expected for age 0+ kokanee is in the -53dB bin while age 0+ whitefish are likely to show up in the -47dB bin. The larger size of older whitefish compared to kokanee can be seen also on the acoustic scale in Figure 13. Note that fork length equivalent sizes for 3dB intervals or bins are shown in Appendix 2b.

The above information was used to assist in interpreting the actual echo target strength distributions which are on the same acoustic scale. Below 15m depth size distributions were not evident and no modes were detected, presumably as fish densities were too low and sizes of fish were too varied between transects. However, above 15m depth there was a clear bimodal distribution observed from combined transects (Figure 14). The smaller mode at -53dB is thought to represent kokanee fry as these were the only fish captured in mid-water habitat in the 36-52mm size range. The interesting feature is the larger mode including fish from 100-220mm was by far the large majority (approx. 60%) of echo targets. This was not typical of a kokanee population which would normally show about 60-75% age 0 and the combined age 1, 2 and 3 fish comprising the remainder. Therefore the distribution provides evidence that the majority of targets were whitefish rather than kokanee, which is supported by gillnet catches. The kokanee fry component of 10% plus another 3-5% of 1-3 kokanee, would put the total kokanee population in the order of 13-15% of the total acoustic population. It is worth noting that the acoustic size distribution from the 1988 survey did not show a mode for kokanee fry sized fish indicating the likelihood that numbers of kokanee at that time were lower than in August 2000 (Figure 15). The larger fish component was also dominated by the -44 and -41dB bins in 1988, which was similar to August 2000. Given the larger average size of whitefish in 1988 compared with 2000, one would have expected this to show up in an acoustic size distribution, unless all the largest whitefish were on the surface where they were not detected with the echosounder.

SUMMARY

The 2000 acoustic, trawl and gillnet surveys were considered preliminary or reconnaissance level surveys and estimates of fish abundance in pelagic habitat should be considered "ballpark". The estimates provide some initial baseline data and establish reference points for future comparison. A number of improvements to the study design and assessment techniques are needed if a long-term monitoring program is to be successful on this reservoir. Some areas where improvements can be made are: bathymetric mapping, navigation, boats and equipment and survey design. In particular, better quantitative assessment of near surface habitat would improve confidence in abundance estimates and in determining species composition in pelagic habitat.

1. Bathymetric mapping was assembled for this investigation. The mapping should be considered "interim" and better mapping is required to improve navigation and the accuracy of extrapolated fish populations. The map accuracy was reasonable for most of the survey but was found to be in error at some locations based on GPS, depth sounder and radar used during the field surveys.

2. The interim mapping has been provided at a scale of 1:100,000 in a separate Volume to this report along with August 2000 and September 1988 echograms

(Appendices 8-10). We used the same mapping at 1:50,000 scale for navigation in the field and for estimating habitat areas at depth in Appendix 1b.

3. Surface area estimates for Williston Reservoir at full pool varied by as much as 15,200 ha or up to 9% of total area. Elevation at full pool is 672m.

4. Elevation at the time of survey in August 2000 was 666.3m. Pelagic habitat at the time of survey was 80,160 ha and 57% of surface area. The proportions of pelagic to total habitat area were higher for the Peace and Junction Reaches compared with the shallower Finlay and Parsnip.

5. Transect fish densities ranged from 28-219 fish·ha^{-1} and were highest in Finlay Reach. Lowest fish densities were found in the Junction Reach and in the lower half of the Peace Reach near Carbon Creek.

6. Fish were found to be too near the surface to accurately count with a downward looking transducer in Parsnip and Finlay reaches. Estimates of abundance near the surface (i.e., 0-2.5m depth) were made based on extrapolating density distributions to the surface. Finlay was the only reach which presented a significant problem of fish near the surface being missed. Estimates in the top 2.5m may have been up to 60% higher in the Finlay reach.

7. Total abundance of fish (all species) in pelagic habitat was estimated at 5.92 million for the reservoir. Up to 2 million fish may have been missed on the surface of Finlay Reach by the echosounder. The resulting best estimate for total fish in pelagic habitat was 8 million fish.

8. The 1988 and 2000 acoustic population estimates were similar after areas used for extrapolation were standardized. There was evidence that the problem with fish near the surface was even more widespread in 1988 than in 2000, suggesting that actual numbers of fish in pelagic habitat were greater in 1988.

9. Evidence suggests the kokanee population has increased since 1988 and Blackman (1992) concluded that kokanee had increased in numbers and range between 1975 and 1988. Based on simple proportions, it appears that the kokanee population may be currently in the order of one million fish and support an estimated spawning run of 40,000-90,000 fish. This is supported by a peak spawner count of 80,000 kokanee following an extensive spawner survey in 2002.

10. The lake whitefish population was estimated at about 5-6 million in pelagic habitat. An additional 4-5 million may occupy shallow water habitat (<20m depth) based on similar CPUE for near shore and offshore gillnets in 1975 and 1988. Total whitefish may therefore be in the order of 9-11 million for the total reservoir.

11. Rainbow trout were difficult to quantify due to their unknown but suspected high vulnerability to capture in surface gillnets. Based on apparent densities in other reservoirs some very rough estimates demonstrate that rainbow do not likely comprise a significant proportion of the total fish population in pelagic habitat of Williston Reservoir – less than 2%.

12. Peamouth chub, although numerous at two gillnet stations, are also viewed as unlikely to comprise a major component of the pelagic fish population. They are likely far more abundant near shore and particularly in association with the bottom as indicated in the literature and by earlier gillnet studies. This however would require further assessment to verify.

13. Trawl and gillnet catches were combined to show four age groups of kokanee and at least 4 ages of lake whitefish. Discrepancies between age interpretation and the resulting estimates of mean length-at-age for both kokanee and whitefish are discussed.

In planning future assessments there are at least three important things to consider. The first is that best sampling conditions may be limited to only 2-3 weeks each year (e.g., first three weeks of August). The second is that the availability of qualified staff and appropriate equipment to conduct acoustic and trawl sampling will be limited as a result of ongoing and other project commitments. Third is the large size and complexity of Williston Reservoir, as it will not be possible to conduct complete surveys of all habitat types every year or even within any single year. Consequently a staged and adaptive approach to assessment is recommended. The objectives would be to address a few key questions each session, which will determine the next logical priority for assessment activities. For example, some modifications to equipment need to be evaluated prior to being incorporated into longer term monitoring. If surface directed trawling is successful at detecting significant numbers of fish and all species, it can be used to verify species composition in gillnets and determine their relative vulnerability to capture. Trawling may turn out to be the only way to quantitatively assess near surface habitat if, for example, an upward looking towable transducer is not feasible to count fish near the surface. It is recommended that a prioritized list of stock assessment objectives and tasks be developed to facilitate a planned development of a monitoring program specific to this reservoir. Since the adaptive approach requires time to fully assess each session before moving to the next, it does not fit well with an annual budgeting cycle (i.e., tasks and budgets are required before results are available). For this reason, consideration should be given to a plan that conducts field assessment every second year (starting in 2004), at least during the initial developmental stages until standard monitoring methods and procedures can be adapted for this system.

RECOMMENDATIONS

A number of improvements to the study design and assessment techniques are needed if long-term monitoring is to be successful. The following recommendations are made to improve mapping, navigation, boats, equipment and techniques, and the survey design.

1. Mapping

Improved Bathymetric mapping is essential to further studies of this reservoir. Increased accuracy is required for safe operation of large boats and is the basis for all extrapolated fish populations since habitat area and volumes change with changing water levels – this is particularly true in the shallower Parsnip and Finlay Reaches. One of the goals should be to improve accuracy of transect zone by depth estimates provided in Appendix 1b. There are at least 4 different options for improving the bathymetric coverage for the reservoir:

a) Aerial photography at a number of different water levels would enable accurate mapping of the shorelines at different elevations between the full pool and maximum drawdown. This would also enable accurate mapping of exposed shoal areas at low pool levels.
b) A reconnaissance level Hydrometric Chart based on transects at 500m intervals conducted by the Canadian Hydrometric Services would provide accurate and reliable bathymetry. Discussions with CHS staff are recommended to determine how they deal with mapping of underwater hazards. Ideally for navigating and trawling it is the elevation of treetops that is more critical than the bottom elevation.
c) A preliminary hydrometric survey can be conducted by Canadian Hydrographic Services for lesser money – resolution would be based on transects every kilometer. The same issue applies with tree tops as mentioned in item 2.
d) Contract a more thorough assembly of the 1:20,000 pre-impoundment topographic mapping that was undertaken in June 2000. Some limited ground truthing (GPS coordinated echosounding) is recommended to fill in gaps where there was either no contour mapping done or where contours were clearly in error. It is apparently necessary to join all existing contour lines between map sheets in order that contours become polygons from which areas can be generated by computer.

2. Navigation

A navigation system which links bathymetric charts with a GPS unit would aid in navigating and sampling selected habitats more efficiently. Acquiring an echosounder that can track the bottom at planing speeds would improve safety when running between sites and reduce time in locating drop-offs, shoals etc.

3. Boats

The boats used for conducting the acoustic and trawl surveys were marginal for this type of work – i.e. in remote areas at night with debris, shoal hazards and rough water. Except during ideal weather, the 6.7m (22ft) WLAP trawl boat used in the 2000 survey was too small for this reservoir. It is recommended that the new 8.5m (28') PWFWCP boat be equipped with hydraulics and a custom tow post that can accommodate a trawl winch and boom. There may be some economies in fitting the boat so it could accept an identical winch to the dual drum type on the new WLAP Hydroacoustic boat. This winch could be borrowed for seasonal trawl work on Williston Reservoir and purchased only if it is found to be suitable and is required for longer term monitoring.

The PWFWCP boat could easily be equipped for acoustic surveys as well. Depending on the amount of work, it may be desirable to conduct hydroacoustic work initially from the PWFWCP boat and eventually from a second boat so both surveys could be conducted concurrently. The Hydroacoustic boat stationed out of Victoria would be suitable for acoustic surveys but is still borderline too small for conducting trawl work on this reservoir.

4. Equipment and methods

Modification of trawl gear

Trawling in August 2000 was done using a standard kokanee net (except for the white colored mesh) and considerable time was spent proportionally sampling all habitat from 35m up to 5m using a stepped oblique tow. In retrospect, focussing on surface layers at some locations may have captured more fish and been more useful in calibrating gillnet catches for determining species composition.

a) Trawl gear can be modified to target fish on or near the surface. Some experimentation should be done towing different sized nets (e.g., 5x5m and a 3x7m opening/closing type) on the surface with floats attached to the head bar. The intent is to have enough floatation to enable the net to float on the surface at a variety of different tow speeds and cable lengths. Problems with capture of larger fish are likely to be associated with net avoidance, which can be a result of tow speed, ambient light, surface turbulence and possibly a pressure wave ahead of the net. Depending on whether the avoidance response is to sound, a deeper net such as the 3x7m may be more effective. The 3x7m net can be closed before it is retrieved which may be an advantage in landing larger fish.

b) Surface trawling may be difficult as a result of floating debris. Further experimentation using floats attached to short ropes may be done to trawl either slightly below surface or down 5m to catch fish near but at the surface.

c) Oblique trawling from 5 to 35m may still be required and it is recommended that speeds be increased to near 1m·sec^{-1} and duration per layer be increased in order to increase sample sizes.

d) The white panels on the existing 5x5m net should be replaced with dark colored mesh.

Modification of Acoustic Gear

Standard acoustic surveys are adequate for counting fish below 5m depth and can make some estimates within 5m of the transducer, however, there was clearly a need in some locations on Williston (Finlay and Parsnip Reaches) to count fish within 5 m of the surface. This cannot be accomplished with a downward looking transducer. There are at least two options for deployment of submerged upward looking transducers using one of the existing echosounders.

a) Acquire a fin, planer or "fish" that can be towed at a controlled depth either off the side or aft and off to one side of the boat to avoid turbulence and bubbles. An upward "looking" transducer will be attached to this apparatus and towed along transects while collecting data upwards toward the surface. The transducer would have to be submerged to depths of 15-20m so will be limited to deeper water.

b) Design and construct a fish as indicated above if one is not available for lease or purchase.

c) Borrow or build a stationary platform from which to "hang" an upward looking transducer. A stationary is less desirable than a towed transducer in situations of low fish density. Success of a stationary upward looking tranducer will depend on whether fish densities near the surface are high enough.

The acoustic sampling is still the best method known for quantitative and repeatable enumeration of fish stocks in large lakes and reservoirs. This is really the only technique that can produce estimates of fish density and abundance in open water.

5. **Sampling design**

Sampling design for fish stock assessment needs to be flexible and adaptive enabling priorities to change as the information base improves but also if conditions in the reservoir change (eg. if majority of fish are found in Peace Reach instead of Finlay). The initial design in 2000 was aimed at total, albeit preliminary coverage of the pelagic habitat from all three major basins or arms. The trawling was based on standard oblique methods but did not sample the surface waters. Acoustic surveys were

focused on habitats deeper than 5m and were confined to areas >20m depth. Gillnet surveys were set on the surface in pelagic habitat only.

Further assessment of pelagic habitat should also include a number of different sampling methods as in August 2000, but also be directed toward better assessment of fish species composition and abundance in near surface habitat. The following is recommended:

a) Some standard acoustic transects be done in all (or at least 3 of 4) reaches at the onset of field sampling in order to determine if the general distribution of fish is similar to August 2000 or different. This will require some preliminary layered analyses of acoustic data onsite. The objective is to determine where the near surface investigations should be focussed.

b) Timing of further field investigations should attempt to take advantage of warmest surface temperatures in order to determine if this assists in interpreting catch data. It is recommended that surveys be planned for the new moon period in mid August 2004 and that preliminary acoustic surveys (item a) be done the week previous. It may turn out that late August or early September is preferred in order to find all species concentrated near the surface.

c) Temperature profiles are recommended at the time of sampling and monthly on either side of sampling. Continuous monitoring of surface temperatures at a few locations on the reservoir during July to September is also recommended.

d) If fish vertical distributions are similar to August 2000, then proceed with near surface work described in items e and f. Otherwise redirect assessment to more standard deep water surveys as in August 2000, but with increased effort on oblique layered trawling.

e) Conduct some experimental trawl sampling near the surface in a location where fish are aggregated near the surface. Some trials with different trawl nets and tow speeds are recommended with concurrent and replicate surface gillnetting in the same general area.

f) Conduct some experimental echosounding with upward looking apparatus in the same vicinity (i.e., where fish are aggregated near the surface). Evaluate methods (stationary vs towed) and compare results with downward looking assessment for similar depth strata to ensure consistency between the two data sets.

g) Repeat August 2000 gillnet survey of pelagic habitat with floating gillnets.

h) Conduct limited gillnet sets on floats at 5m of depth at a site or two to compare with surface gillnet catches at the same stations and Blackman's earlier findings. The intent is to verify the success of surface netting compared with submerged nets.

i) Evaluation of surface trawls will be aimed at comparing results with surface gillnet catches in order to improve our understanding of relative species vulnerability to gillnets and to determine species composition in pelagic habitat. CPUE on surface trawls should also be compared with upward looking acoustic densities to further evaluate trawl efficiency.

j) Once we have more confidence in summertime fish distributions in pelagic habitat, a study design can be developed which focuses proportionally more sampling effort on areas where fish are known to be concentrated. This should improve reliability and reduce sampling intensity.

k) For kokanee, conduct preliminary surveys to identify key spawning streams and then conduct annual counts on key streams. Compare counts with August 2000 'ballpark' estimates for spawning escapement. Determine where key areas are for kokanee recruitment.

l) For both kokanee and whitefish it is recommended that all otoliths and scales be interpreted by a different contractor to see if some of the differences between trawl and gillnet age interpretations can be reconciled.

m) Consideration should be given to conducting future field surveys every second year in order to use an adaptive management approach rather than be limited by annual budget cycles, which do not enable time for data analyses.

Some key questions that should to be addressed in future fish stock assessments are:

a) How variable are pelagic fish distributions from year to year at the same time of year?
b) How critical are surface temperatures and temperature profiles for assessing fish species composition and abundance in pelagic habitat? The aim is to ensure a monitoring program is consistent in terms of sampling times and conditions.
c) Which reaches or sub-reaches support more kokanee or more whitefish, and what is the minimum sampling required for monitoring these populations?
d) Can a combination of surface and oblique trawling effectively capture sufficient numbers of whitefish, rainbow, kokanee and peamouth chub to establish species composition in pelagic habitat?
e) Can gillnets be "calibrated" using the above trawl information to better reflect species compostion in pelagic habitat?
f) Can sampling methods developed for assessment of pelagic fish populations be used to begin assessment of embayments and shallow areas of Williston Reservoir?

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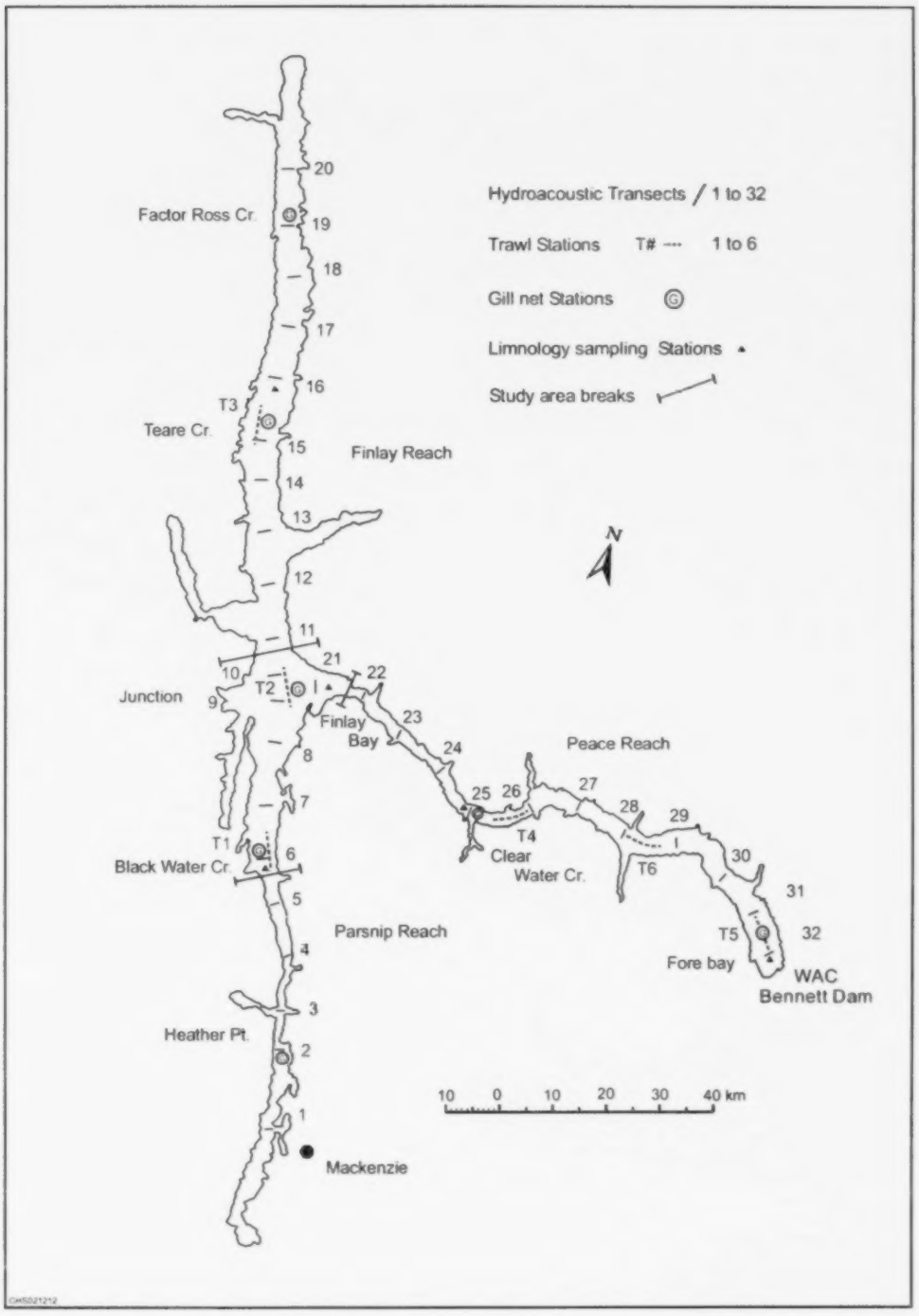


Figure 1. Map of Williston Reservoir showing locations of acoustic transects, trawl stations, and gill net sites, August 2000.

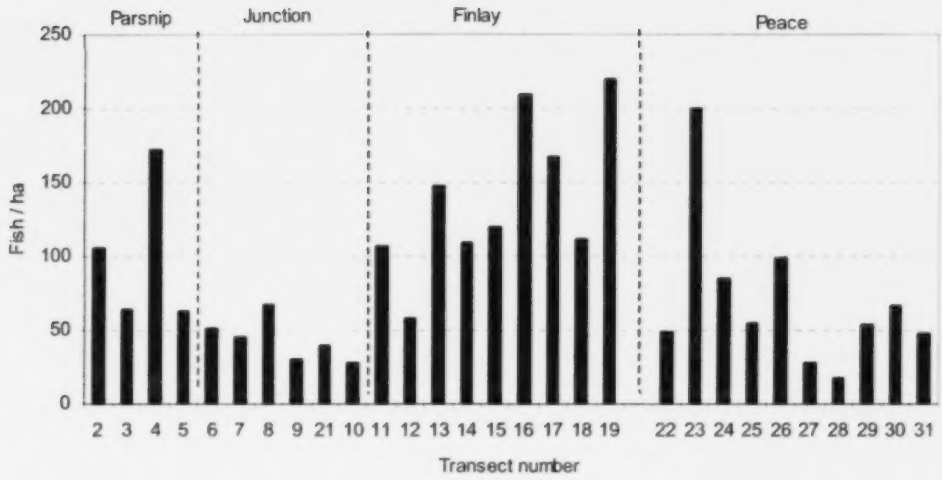


Figure 2. Longitudinal density distributions of Williston Reservoir fish by transect based on acoustic survey data, August 2000.

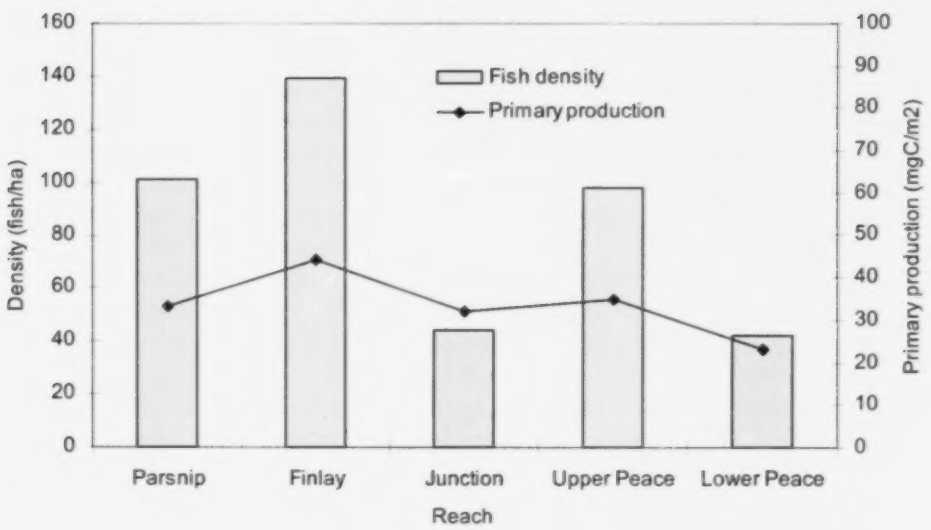


Figure 3. Trends in primary production and average fish densities by reach based on limnological and acoustic surveys in 2000.

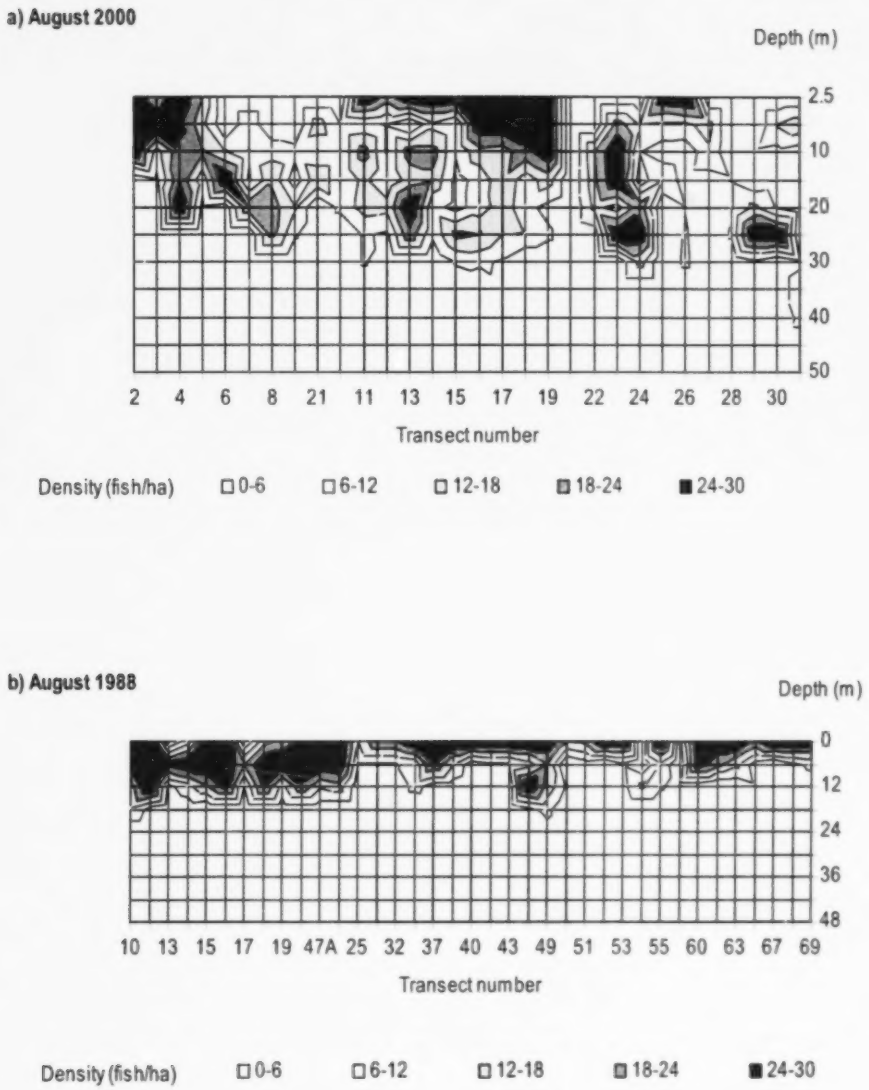


Figure 4. Vertical (and horizontal) distributions of fish by densities intervals for Williston Reservoir based on **a)** August 2000 and **b)** September 1988 acoustic surveys.

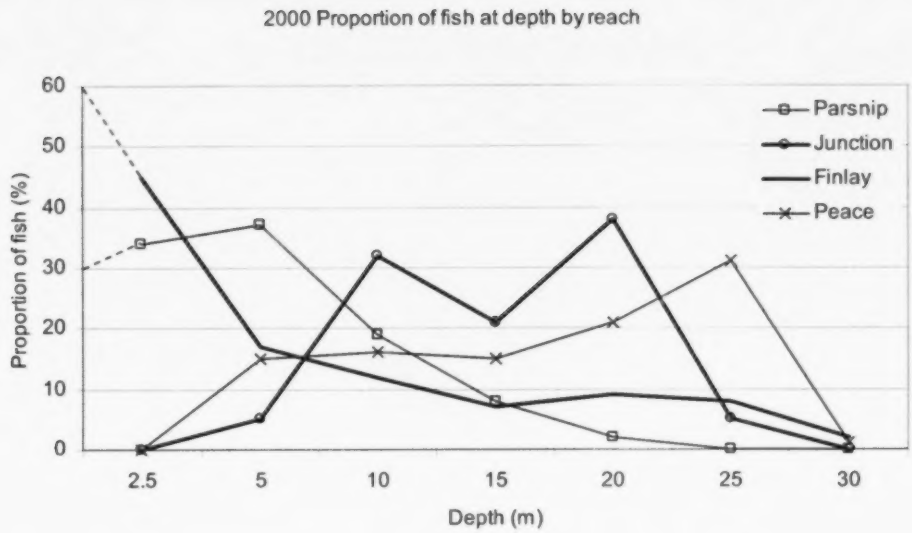


Figure 5. Proportion of fish numbers by depth and reach during August 2000 based on acoustic survey data.

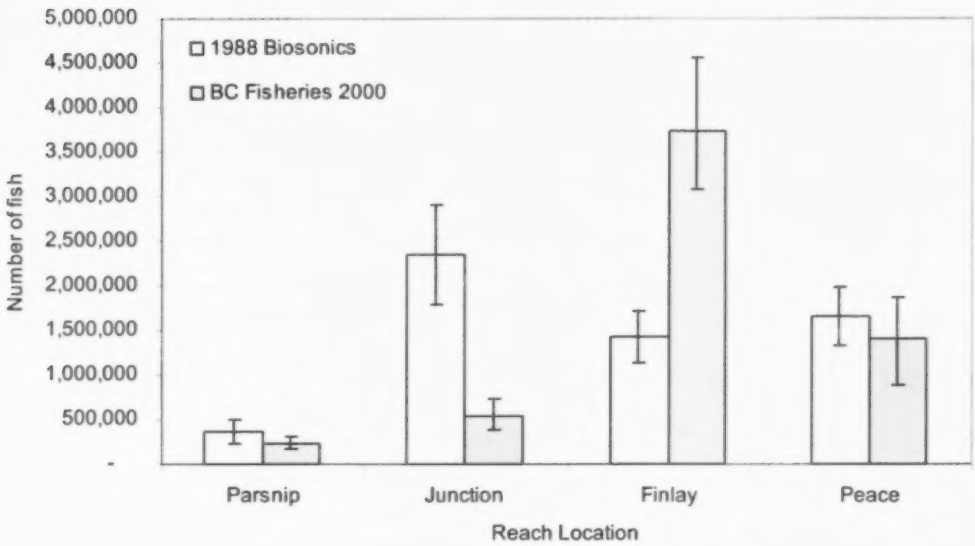


Figure 6. Comparison of fish abundance estimates by reach for pelagic habitat between August 2000 and September 1988 acoustic surveys of Williston Reservoir.

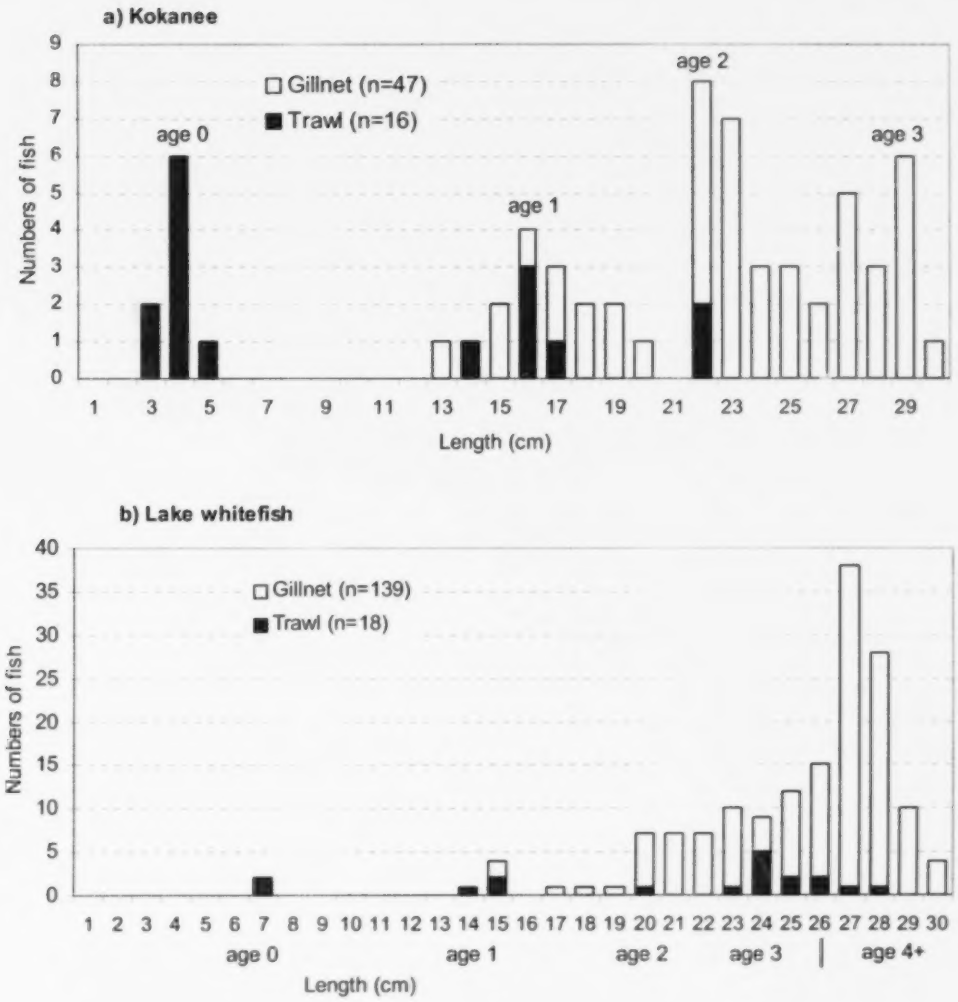


Figure 7. Length frequency distributions for a) kokanee and b) lake whitefish from trawl and gill net catches in Williston Reservoir during August 2000. Ages have been based on aged trawl samples and length frequency modes

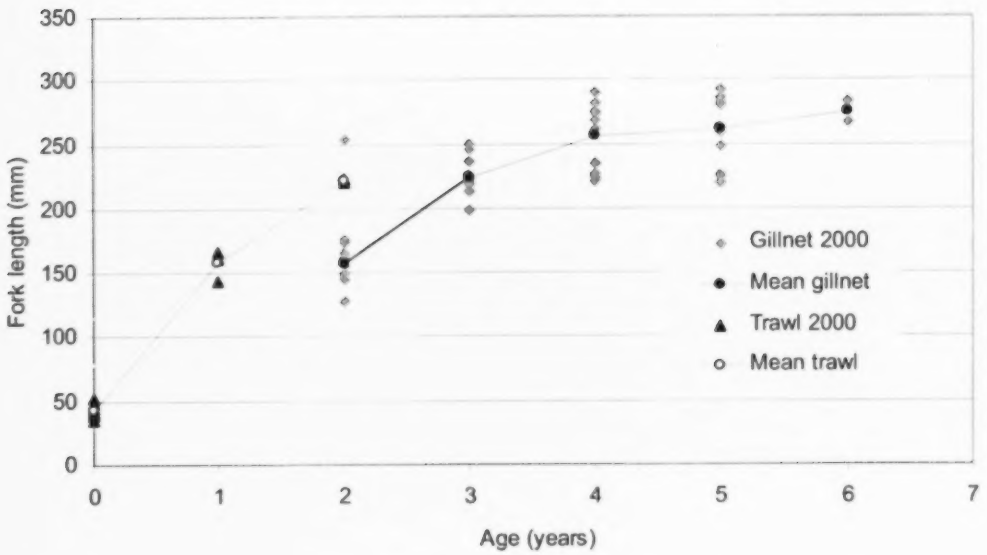


Figure 8. Kokanee length-at-age for Williston Reservoir from August 2000 trawl and gillnet samples.

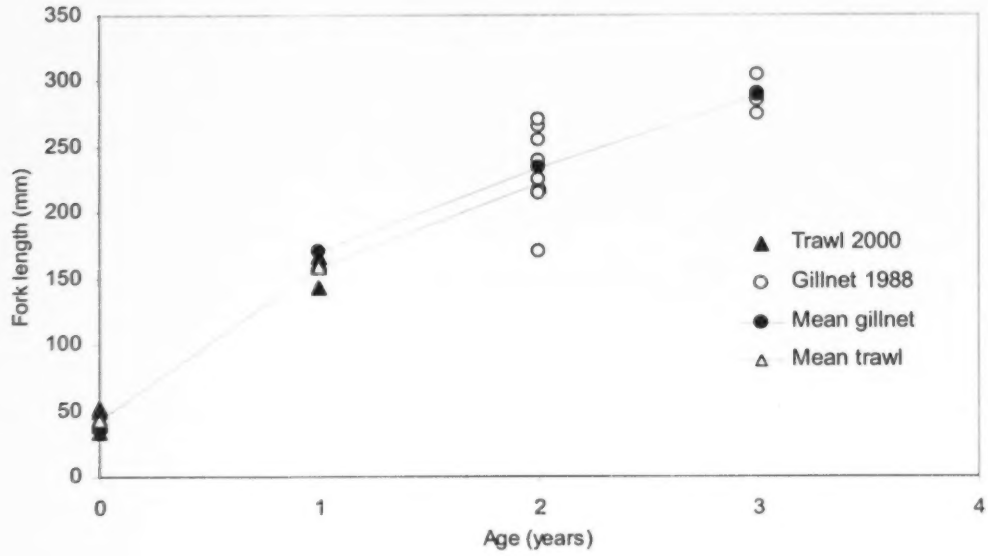


Figure 9. Kokanee length-at-age for Williston Reservoir based on 1988 gillnet and 2000 trawl net samples.

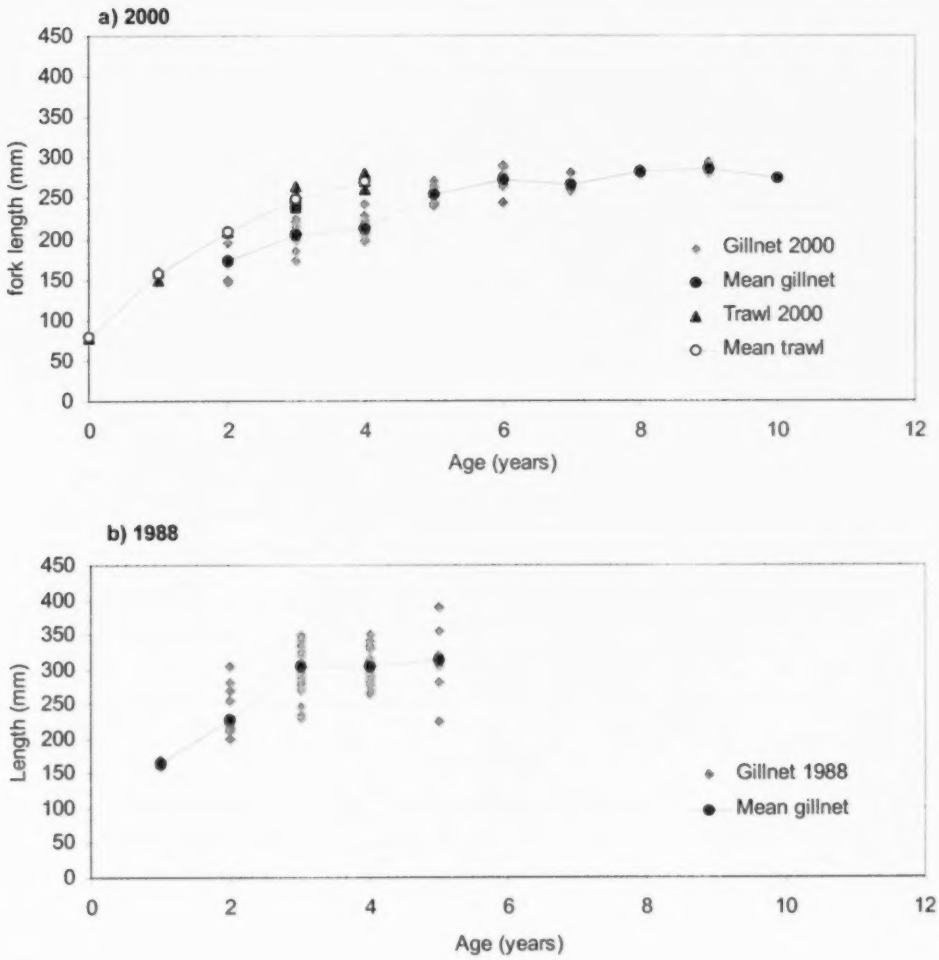


Figure 10. Lake whitefish length-at-age from a) trawl and gillnet samples in August 2000 and b) gillnet samples in August 1988 from Blackman (1992).

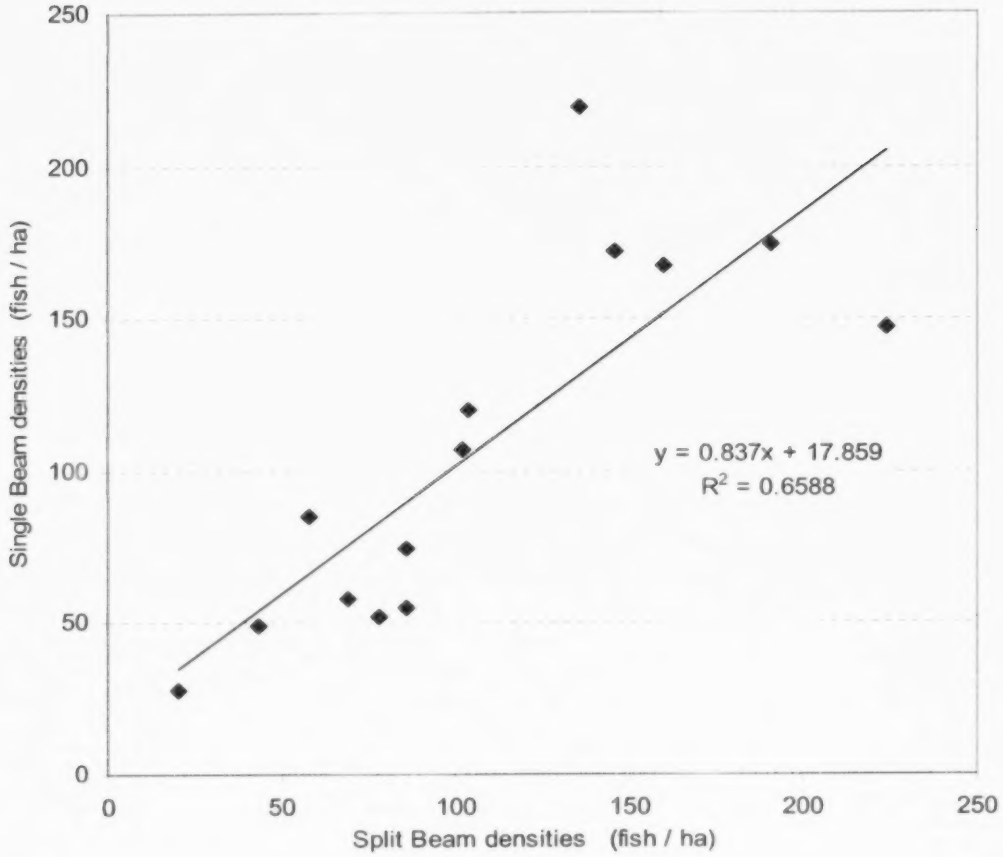


Figure 11. Comparison of 120 KHz split beam and 70 KHz single beam acoustic density data from Williston Reservoir August 2000 survey.

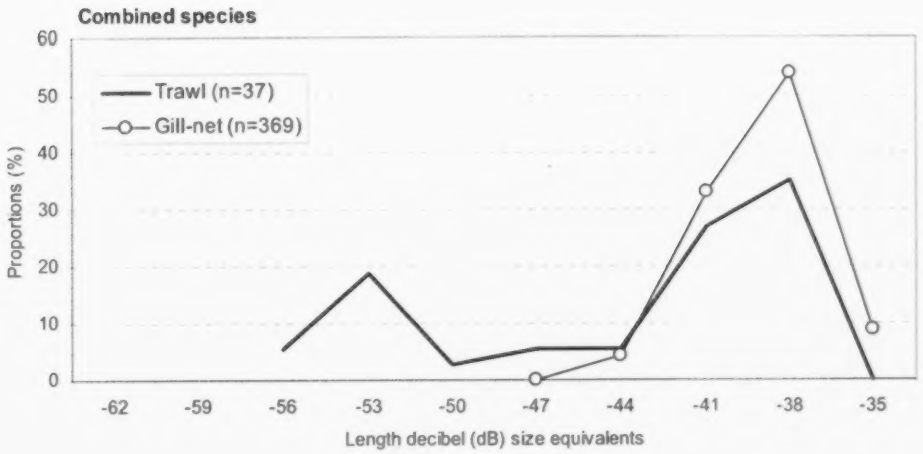


Figure 12. Comparison of trawl and gillnet size distributions (in decibels) for combined fish in pelagic habitat of Williston Reservoir during August 2000 based on Love's (1977) dorsal aspect formula.

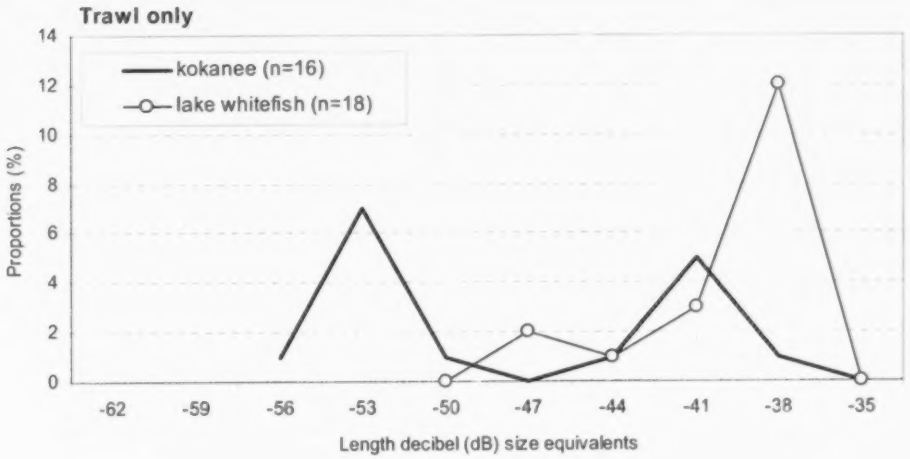


Figure 13. Comparison of kokanee and lake whitefish size distributions (in decibels) based on Love's (1977) dorsal aspect formula for August 2000 trawl samples.

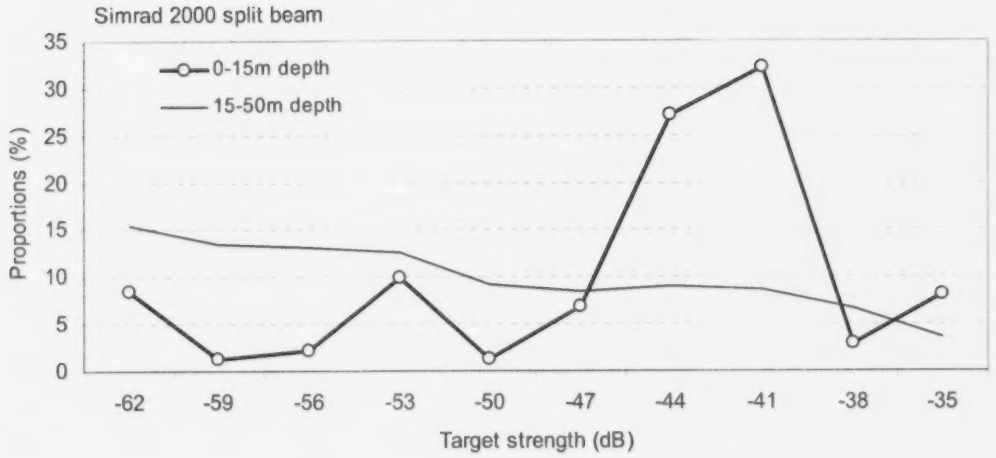


Figure 14. Comparison of echo target strength (fish size) distributions above and below 15m depth in Williston Reservoir based on August 2000 acoustic sampling.

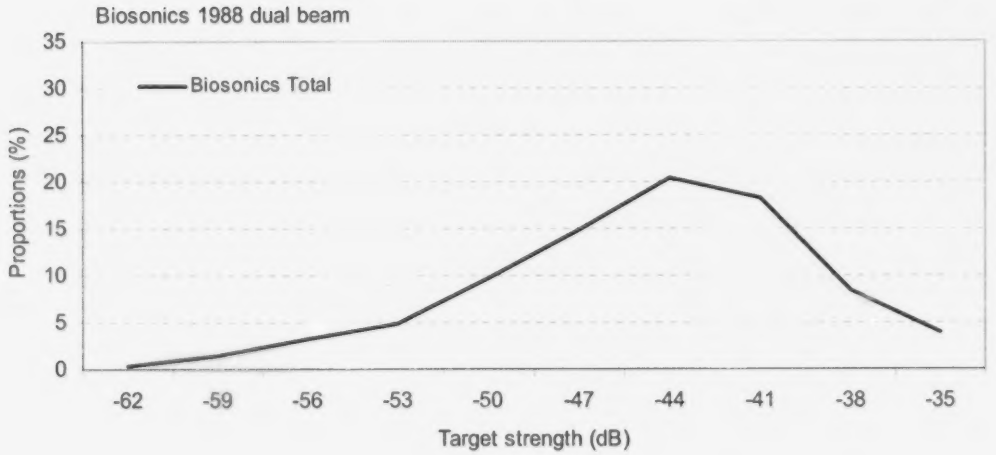
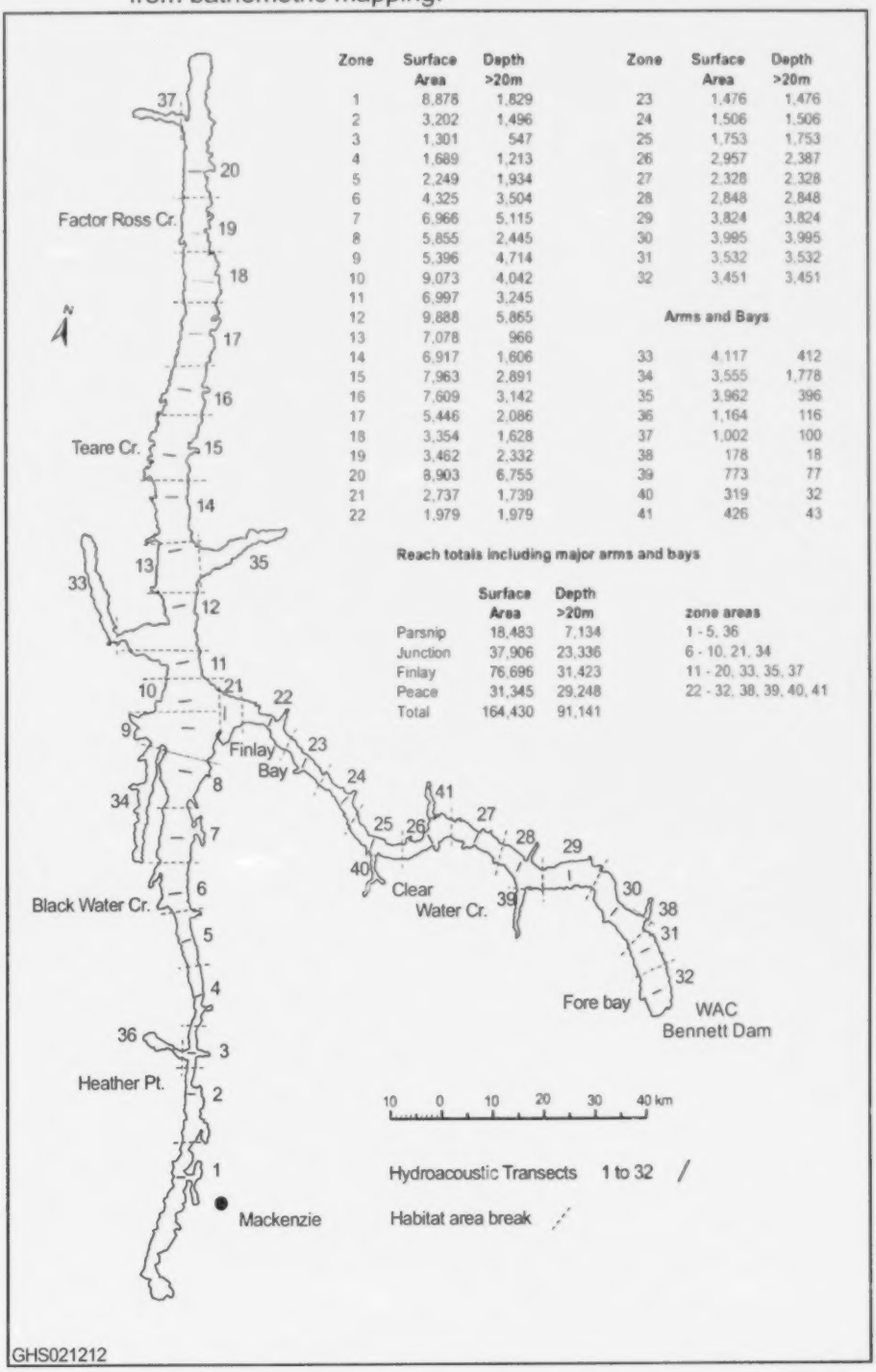


Figure 15. Echo target strength (fish size) distribution in Williston Reservoir based on September 1988 acoustic sampling by Johnson and Yesaki (1989).

Appendix 1a. Map of Williston Reservoir showing habitat areas by transect derived from bathemetric mapping.



Zone	Surface Area	Depth >20m	Zone	Surface Area	Depth >20m
1	8,878	1,829	23	1,476	1,476
2	3,202	1,496	24	1,506	1,506
3	1,301	547	25	1,753	1,753
4	1,689	1,213	26	2,957	2,387
5	2,249	1,934	27	2,328	2,328
6	4,325	3,504	28	2,848	2,848
7	6,966	5,115	29	3,824	3,824
8	5,855	2,445	30	3,995	3,995
9	5,396	4,714	31	3,532	3,532
10	9,073	4,042	32	3,451	3,451
11	6,997	3,245			
12	9,888	5,865		Arms and Bays	
13	7,078	966			
14	6,917	1,606	33	4,117	412
15	7,963	2,891	34	3,555	1,778
16	7,609	3,142	35	3,962	396
17	5,446	2,086	36	1,164	116
18	3,354	1,628	37	1,002	100
19	3,462	2,332	38	178	18
20	8,903	6,755	39	773	77
21	2,737	1,739	40	319	32
22	1,979	1,979	41	426	43

Reach totals including major arms and bays

	Surface Area	Depth >20m	zone areas
Parsnip	18,483	7,134	1 - 5, 36
Junction	37,906	23,336	6 - 10, 21, 34
Finlay	76,696	31,423	11 - 20, 33, 35, 37
Peace	31,345	29,248	22 - 32, 38, 39, 40, 41
Total	164,430	91,141	

Appendix 1b. Williston Reservoir habitat areas by depth for 41 zone areas interpolated from bathymetric mapping and 1988 echograms from acoustic surveys.

Reach Zones		1	2	3	4	5	Parsnip 1 - 5	6	7	8	9	10	21	Junction 6 - 10, 21	34	36
Elevation	Depth			3 + 36							9 + 34					
672	Full Pool	8878	3202	2465	1689	2249	18483	4325	6966	5855	8951	9073	2737	37907	3555	1164
671	1	8526	3117	2369	1665	2233	17910	4284	6873	5685	8739	8821	2687	37090	3466	1112
670	2	8173	3031	2273	1641	2218	17337	4243	6781	5514	8527	8570	2637	36272	3377	1059
669	3	7821	2946	2177	1618	2202	16763	4202	6688	5344	8315	8318	2587	35455	3288	1007
668	4	7468	2861	2081	1594	2186	16190	4161	6596	5173	8103	8067	2537	34637	3200	954
667	5	7116	2776	1986	1570	2170	15617	4120	6503	5003	7891	7815	2488	33820	3111	902
666	6	6763	2690	1890	1546	2155	15044	4079	6411	4832	7679	7564	2438	33002	3022	850
665	7	6411	2605	1794	1522	2139	14470	4038	6318	4662	7467	7312	2388	32185	2933	797
664	8	6058	2520	1698	1499	2123	13897	3997	6226	4491	7255	7061	2338	31367	2844	745
663	9	5706	2434	1602	1475	2107	13324	3956	6133	4321	7043	6809	2288	30550	2755	693
662	10	5353	2349	1506	1451	2092	12751	3915	6041	4150	6832	6558	2238	29732	2666	640
661	11	5001	2264	1410	1427	2076	12177	3873	5948	3980	6620	6306	2188	28915	2577	588
660	12	4648	2178	1314	1403	2060	11604	3832	5855	3809	6408	6054	2138	28097	2489	535
659	13	4296	2093	1218	1380	2044	11031	3791	5763	3639	6196	5803	2088	27280	2400	483
658	14	3943	2008	1122	1356	2029	10458	3750	5670	3468	5984	5551	2038	26462	2311	431
657	15	3591	1923	1027	1332	2013	9884	3709	5578	3298	5772	5300	1989	25645	2222	378
656	16	3238	1837	931	1308	1997	9311	3668	5485	3127	5560	5048	1939	24827	2133	326
655	17	2886	1752	835	1284	1981	8738	3627	5393	2957	5348	4797	1889	24010	2044	274
654	18	2533	1667	739	1261	1966	8165	3586	5300	2786	5136	4545	1839	23192	1955	221
653	19	2181	1581	643	1237	1950	7591	3545	5208	2616	4924	4294	1789	22375	1866	169
652	20	1829	1496	547	1213	1934	7019	3504	5115	2445	4712	4042	1739	21557	1778	116
651	21	1524	1401	515	1195	1930	6565	3498	5107	2441	4594	3996	1727	21363	1689	64
650	22	1219	1306	482	1177	1926	6110	3491	5100	2438	4476	3950	1715	21170	1600	12
649	23	915	1210	450	1159	1922	5656	3485	5092	2434	4359	3904	1703	20976	1511	
648	24	610	1115	417	1141	1919	5202	3478	5085	2430	4241	3859	1690	20783	1422	
647	25	305	1020	385	1123	1915	4748	3472	5077	2427	4123	3813	1678	20589	1333	
646	26			353	1105	1911	3368	3465	5069	2423	4005	3767	1666	20396	1244	
645	27			320	1087	1907	3314	3459	5062	2420	3887	3721	1654	20202	1155	
644	28			288	1069	1903	3260	3452	5054	2416	3770	3675	1642	20009	1067	
643	29			255	1051	1899	3206	3446	5046	2412	3652	3629	1630	19815	978	
642	30			223	1033	1895	3151	3439	5039	2409	3534	3583	1617	19621	889	
641	31			190	1015	1891	3097	3433	5031	2405	3530	3537	1605	19542	800	
640	32			158	997	1888	3043	3426	5024	2401	3526	3492	1593	19462	711	
639	33			126	979	1884	2989	3420	5016	2398	3522	3446	1581	19382	622	
638	34			93	961	1880	2934	3413	5008	2394	3518	3400	1569	19303	533	
637	35			61	943	1876	2880	3407	5001	2391	3514	3354	1557	19223	444	
636	36				925	1872	2798	3400	4993	2387	3510	3308	1487	19086	355	
635	37				908	1868	2776	3394	4985	2383	3507	3262	1417	18948	267	
634	38				890	1864	2754	3387	4978	2380	3503	3216	1347	18811	178	
633	39				872	1861	2732	3381	4970	2376	3499	3170	1277	18674	89	
632	40				854	1857	2710	3375	4963	2372	3495	3125	1208	18536		

Appendix 1b. (continued)

Reach							Parsnip								Junction		
Zones		1	2	3	4	5	1 - 5	6	7	8	9	10	21	6 -10, 21	34	36
Elevation	Depth			3 + 36							9 + 34					
631	41				836	1853	2688	3368	4955	2369	3491	3079	1138	18399		
630	42				818	1849	2667	3362	4947	2365	3487	3033	1068	18262		
629	43				800	1845	2645	3355	4940	2361	3483	2987	998	18125		
628	44				782	1841	2623	3349	4932	2358	3479	2941	929	17987		
627	45				764	1837	2601	3342	4924	2354	3475	2895	859	17850		
626	46				746	1828	2573	3336	4917	2351	3471	2884		16958		
625	47				728	1818	2546	3329	4909	2347	3467	2873		16925		
624	48				710	1808	2518	3323	4902	2343	3463	2861		16892		
623	49				692	1799	2490	3316	4894	2340	3459	2850		16859		
622	50				674	1789	2463	3310	4886	2336	3455	2838		16826		
621	51					1779	1779	3303	4879	2332	3435	2827		16776		
620	52					1770	1770	3297	4871	2329	3414	2816		16726		
619	53					1760	1760	3290	4864	2325	3393	2804		16676		
618	54					1750	1750	3284	4856	2321	3372	2793		16626		
617	55					1741	1741	3277	4848	2318	3351	2782		16576		
616	56							3271	4841	2314	3330	2770		16526		
615	57							3265	4833	2311	3309	2759		16476		
614	58							3258	4825	2307	3288	2748		16426		
613	59							3252	4818	2303	3267	2736		16376		
612	60							3245	4810	2300	3246	2725		16326		
611	61								4803	2296	3225	2714		13037		
610	62								4795	2292	3204	2702		12994		
609	63								4787	2289	3183	2691		12950		
608	64								4780	2285	3162	2680		12907		
607	65								4772	2282	3141	2668		12863		
606	66									2278	3133	2662		8074		
605	67									2274	3126	2657		8057		
604	68									2271	3118	2651		8040		
603	69									2267	3110	2645		8022		
602	70									2263	3102	2640		8005		
601	71										3094	2634		5728		
600	72										3086	2628		5715		
599	73										3079	2623		5701		
598	74										3071	2617		5688		
597	75										3063	2611		5674		
596	76										3055	2606		5661		
595	77										3047	2600		5647		
594	78										3039	2594		5634		
593	79										3031	2589		5620		
592	80										3024	2583		5607		

Appendix 1b. (continued)

Reach Zones		11	12	13	14	15	16	17	18	19	20	Finlay	33	35	37
Elevation	Depth		12 + 33	13 +35							20 + 37	11 - 20			
672	Full Pool	6997	14005	11040	6917	7963	7609	5446	3354	3462	9905	76698	4117	3962	1002
671	1	6809	13598	10536	6651	7709	7386	5278	3268	3406	9748	74389	3932	3784	956
670	2	6622	13191	10033	6386	7456	7162	5110	3181	3349	9590	72080	3747	3606	911
669	3	6434	12784	9529	6120	7202	6939	4942	3095	3293	9433	69771	3561	3427	866
668	4	6247	12377	9025	5855	6949	6716	4774	3009	3236	9275	67462	3376	3249	821
667	5	6059	11970	8522	5589	6695	6492	4606	2923	3180	9118	65153	3191	3071	776
666	6	5871	11563	8018	5324	6441	6269	4438	2836	3123	8960	62843	3005	2893	731
665	7	5684	11156	7514	5058	6188	6046	4270	2750	3067	8803	60534	2820	2714	686
664	8	5496	10749	7010	4793	5934	5822	4102	2664	3010	8645	58225	2635	2536	641
663	9	5309	10342	6507	4527	5681	5599	3934	2577	2954	8488	55916	2450	2358	596
662	10	5121	9935	6003	4262	5427	5376	3766	2491	2897	8330	53607	2264	2179	551
661	11	4933	9528	5499	3996	5173	5152	3598	2405	2841	8173	51298	2079	2001	506
660	12	4746	9121	4996	3730	4920	4929	3430	2318	2784	8015	48989	1894	1823	461
659	13	4558	8714	4492	3465	4666	4705	3262	2232	2728	7858	46680	1709	1644	416
658	14	4371	8307	3988	3199	4413	4482	3094	2146	2671	7700	44371	1523	1466	371
657	15	4183	7900	3485	2934	4159	4259	2926	2060	2615	7543	42062	1338	1288	325
656	16	3995	7493	2981	2668	3905	4035	2758	1973	2558	7385	39752	1153	1109	280
655	17	3808	7086	2477	2403	3652	3812	2590	1887	2502	7228	37443	968	931	235
654	18	3620	6679	1973	2137	3398	3589	2422	1801	2445	7070	35134	782	753	190
653	19	3433	6272	1470	1872	3145	3365	2254	1714	2389	6913	32825	597	575	145
652	20	3245	5865	966	1606	2891	3142	2086	1628	2332	6755	30516	412	396	100
651	21	3235	5835	947	1555	2873	3122	2080	1623	2320	6604	30195	226	218	55
650	22	3225	5806	929	1505	2854	3102	2075	1618	2307	6453	29874	41	40	10
649	23	3215	5776	910	1454	2836	3083	2069	1614	2295	6302	29552			
648	24	3205	5746	892	1403	2818	3063	2064	1609	2282	6150	29231			
647	25	3195	5717	873	1352	2799	3043	2058	1604	2270	5999	28910			
646	26	3190	5687	855	1302	2781	3023	2052	1599	2257	5848	28595			
645	27	3186	5657	836	1251	2763	3004	2047	1594	2245	5697	28279			
644	28	3181	5628	817	1200	2744	2984	2041	1590	2233	5546	27964			
643	29	3177	5598	799	1150	2726	2964	2036	1585	2220	5395	27648			
642	30	3173	5568	780	1099	2707	2944	2030	1580	2208	5243	27333			
641	31	3168	5538	762	1048	2689	2925	2024	1575	2195	5092	27017			
640	32	3164	5509	743	997	2671	2905	2019	1570	2183	4941	26701			
639	33	3159	5479	725	947	2652	2885	2013	1566	2170	4790	26386			
638	34	3155	5449	706	896	2634	2865	2008	1561	2158	4639	26070			
637	35	3150	5420	687	845	2616	2845	2002	1556	2145	4488	25755			
636	36	3144	5390	669	811	2597	2826	1996	1551	2103		21088			
635	37	3138	5360	650	778	2579	2806	1991	1546	2060		20908			
634	38	3132	5331	632	744	2561	2786	1985	1542	2017		20729			
633	39	3126	5301	613	710	2542	2766	1980	1537	1974		20549			
632	40	3120	5271	594	676	2524	2747	1974	1532	1931		20370			

Appendix 1b. (continued)

Reach Zones		11	12	13	14	15	16	17	18	19	20	Finlay 11 - 20			
Elevation	Depth		12 + 33	13 +35							20 + 37				
631	41	3114	5242	576	642	2506	2727	1969	1527	1888		20190			
630	42	3108	5212	557	609	2487	2707	1963	1522	1845		20010			
629	43	3102	5182	539	575	2469	2687	1957	1518	1802		19831			
628	44	3096	5153	520	541	2450	2668	1952	1513	1759		19651			
627	45	3090	5123	502	507	2432	2648	1946	1508	1716		19472			
626	46	3084	5093	483	499	2414	2601	1941		1407		17521			
625	47	3078	5063	464	491	2395	2554	1935		1097		17078			
624	48	3072	5034	446	483	2377	2507	1929		787		16634			
623	49	3066	5004	427	475	2359	2459	1924		478		16191			
622	50	3060	4974	409	467	2340	2412	1918		168		15748			
621	51	3054	4945	390	458	2322	2365	1582				15117			
620	52	3048	4915	372	450	2304	2318	1247				14653			
619	53	3042	4885	353	442	2285	2271	911				14190			
618	54	3036	4856	334	434	2267	2224	575				13726			
617	55	3030	4826	316	426	2249	2177	240				13263			
616	56	3023	4796	297	418	2053	2130					12717			
615	57	3017	4767	279	410	1857	2083					12412			
614	58	3011	4737	260	402	1661	2036					12107			
613	59	3005	4707	241	394	1465	1989					11801			
612	60	2999	4678	223	385	1269	1942					11496			
611	61		4648	215	377	1073						6314			
610	62		4618	208	369	877						6072			
609	63		4588	201	361	681						5831			
608	64		4559	193	353	485						5590			
607	65		4529	186	345	289						5349			
606	66		4109	178	337							4624			
605	67		3688	171	329							4188			
604	68		3268	163	321							3752			
603	69		2848	156	312							3316			
602	70		2427	149	304							2880			
601	71		2007									2007			
600	72		1587									1587			
599	73		1166									1166			
598	74		746									746			
597	75		326									326			
596	76														
595	77														
594	78														
593	79														
592	80														

Appendix 1b. (continued)

Reach Zones		22	23	24	25	26	27	28	29	30	31	32	Peace 22 - 32	38	39	40	41
Elevation	Depth				25 + 40	26 + 41		28 +39		30 +38							
672	Full Pool	1979	1476	1506	2072	3383	2328	3621	3824	4173	3532	3451	31345	178	773	319	426
671	1	1979	1476	1506	2069	3333	2328	3600	3824	4173	3532	3451	31271	170	738	305	407
670	2	1979	1476	1506	2066	3283	2328	3579	3824	4173	3532	3451	31198	162	704	291	388
669	3	1979	1476	1506	2063	3234	2328	3559	3824	4173	3532	3451	31124	154	669	276	369
668	4	1979	1476	1506	2060	3184	2328	3538	3824	4173	3532	3451	31050	146	634	262	350
667	5	1979	1476	1506	2057	3134	2328	3517	3824	4173	3532	3451	30977	138	599	247	330
666	6	1979	1476	1506	2053	3084	2328	3496	3824	4173	3532	3451	30903	130	564	233	311
665	7	1979	1476	1506	2050	3034	2328	3475	3824	4173	3532	3451	30829	122	530	219	292
664	8	1979	1476	1506	2047	2985	2328	3455	3824	4173	3532	3451	30755	114	495	204	273
663	9	1979	1476	1506	2044	2935	2328	3434	3824	4173	3532	3451	30682	106	460	190	254
662	10	1979	1476	1506	2041	2885	2328	3413	3824	4173	3532	3451	30608	98	425	176	234
661	11	1979	1476	1506	2038	2835	2328	3392	3824	4173	3532	3451	30534	90	390	161	215
660	12	1979	1476	1506	2035	2785	2328	3371	3824	4173	3532	3451	30461	82	356	147	196
659	13	1979	1476	1506	2032	2736	2328	3351	3824	4173	3532	3451	30387	74	321	133	177
658	14	1979	1476	1506	2029	2686	2328	3330	3824	4173	3532	3451	30313	66	286	118	158
657	15	1979	1476	1506	2026	2636	2328	3309	3824	4173	3532	3451	30240	58	251	104	139
656	16	1979	1476	1506	2022	2586	2328	3288	3824	4173	3532	3451	30166	50	216	89	119
655	17	1979	1476	1506	2019	2536	2328	3267	3824	4173	3532	3451	30092	42	182	75	100
654	18	1979	1476	1506	2016	2487	2328	3247	3824	4173	3532	3451	30018	34	147	61	81
653	19	1979	1476	1506	2013	2437	2328	3226	3824	4173	3532	3451	29945	26	112	46	62
652	20	1979	1476	1506	2010	2387	2328	3205	3824	4172	3532	3451	29870	18	77	32	43
651	21	1969	1456	1486	1998	2313	2249	3173	3814	4137	3497	3433	29525	10	43	18	23
650	22	1959	1437	1466	1986	2240	2170	3140	3804	4102	3462	3414	29180	2	8	3	4
649	23	1949	1417	1447	1974	2166	2090	3108	3793	4067	3427	3396	28835				
648	24	1939	1398	1427	1963	2093	2011	3075	3783	4032	3392	3377	28489				
647	25	1929	1378	1407	1951	2019	1932	3043	3773	3997	3357	3359	28144				
646	26	1919	1359	1387	1939	1946	1853	3010	3763	3962	3322	3341	27799				
645	27	1909	1339	1368	1927	1872	1774	2978	3753	3926	3286	3322	27454				
644	28	1899	1319	1348	1915	1798	1694	2946	3742	3891	3251	3304	27109				
643	29	1889	1300	1328	1903	1725	1615	2913	3732	3856	3216	3285	26764				
642	30	1879	1280	1308	1891	1651	1536	2881	3722	3821	3181	3267	26419				
641	31	1869	1261	1289	1879	1578	1530	2848	3712	3786	3146	3249	26147				
640	32	1859	1241	1269	1868	1504	1524	2816	3702	3751	3111	3230	25875				
639	33	1849	1221	1249	1856	1430	1518	2784	3691	3716	3076	3212	25603				
638	34	1839	1202	1229	1844	1357	1512	2751	3681	3681	3041	3193	25331				
637	35	1829	1182	1210	1832	1283	1505	2719	3671	3646	3006	3175	25059				
636	36	1819	1163	1188	1820	1278	1499	2686	3661	3611	2971	3166	24862				
635	37	1809	1143	1167	1808	1272	1493	2654	3651	3576	2936	3157	24665				
634	38	1799	1124	1145	1796	1266	1487	2621	3640	3541	2901	3147	24468				
633	39	1789	1104	1124	1784	1261	1481	2589	3630	3506	2866	3138	24272				
632	40	1779	1084	1102	1773	1255	1475	2557	3620	3470	3387	3129	24631				

Appendix 1b. (continued)

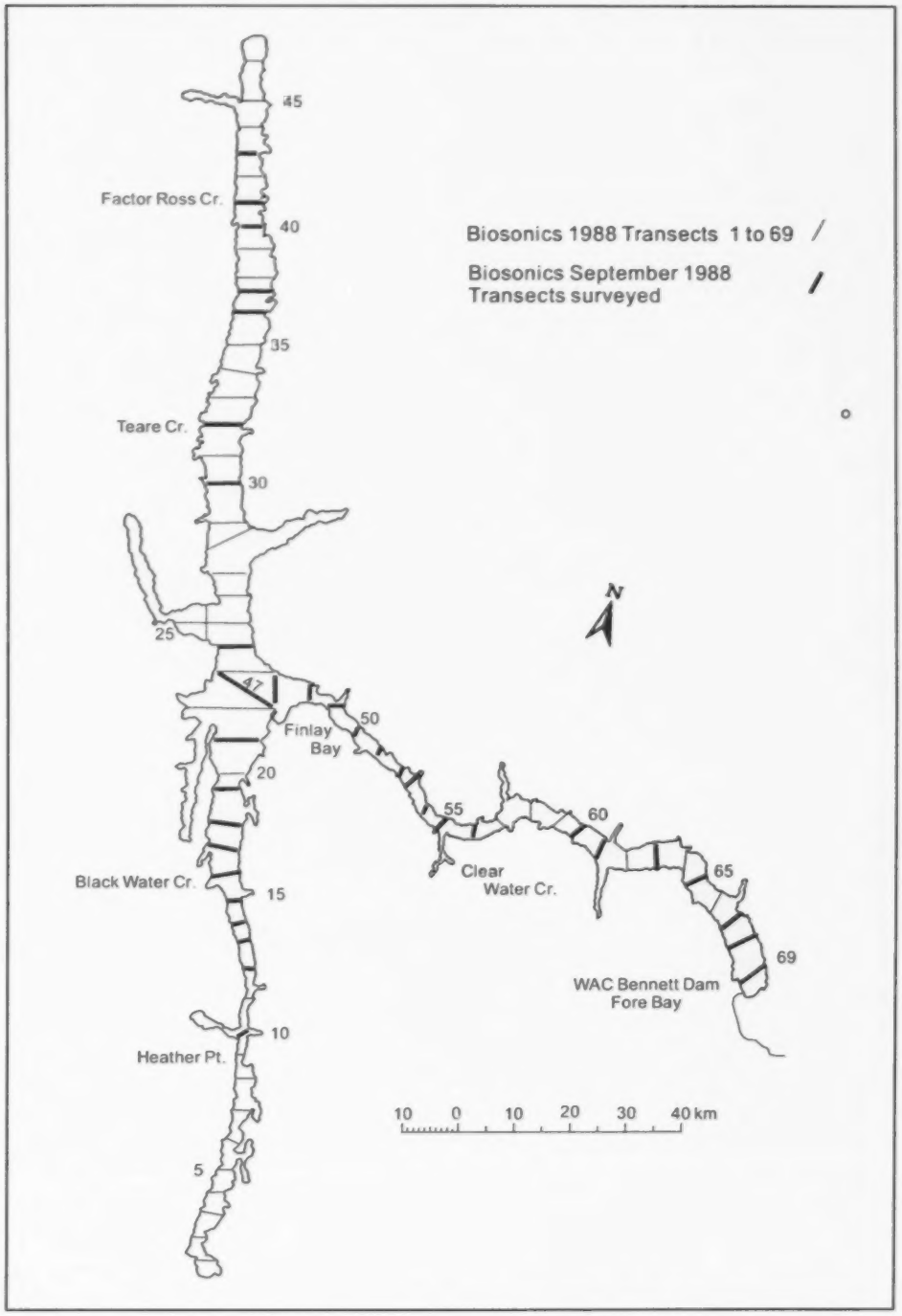
Reach Zones		22	23	24	25	26	27	28	29	30	31	32	Peace 22 - 32	38	39	40	41
Elevation	Depth				25 + 40	26 + 41		28 +39		30 +38							
631	41	1769	1078	1081	1761	1249	1469	2524	3610	3435	3312	3120	24409				
630	42	1759	1072	1059	1749	1244	1463	2492	3600	3400	3237	3111	24186				
629	43	1750	1066	1038	1737	1238	1457	2459	3589	3365	3163	3101	23963				
628	44	1740	1060	1016	1725	1233	1450	2427	3579	3330	3088	3092	23741				
627	45	1730	1054	995	1713	1227	1444	2395	3569	3295	3014	3083	23518				
626	46	1720	1044	974	1711	1221	1438	2383	3559	3288	2939	3074	23352				
625	47	1710	1034	954	1708	1216	1432	2372	3549	3282	2864	3064	23186				
624	48	1700	1024	934	1706	1210	1426	2361	3538	3275	2790	3055	23019				
623	49	1690	1014	914	1703	1204	1420	2350	3528	3269	2715	3046	22853				
622	50	1680	1004	893	1701	1199	1414	2339	3518	3262	2641	3037	22687				
621	51	1670	994	873	1698	1193	1408	2328	3508	3255	2566	3028	22521				
620	52	1660	984	853	1695	1187	1402	2317	3498	3249	2491	3018	22354				
619	53	1650	974	833	1693	1182	1395	2306	3487	3242	2417	3009	22188				
618	54	1640	964	813	1690	1176	1389	2295	3477	3235	2342	3000	22022				
617	55	1630	954	792	1688	1170	1383	2284	3467	3229	2267	2991	21856				
616	56	1575	944	772	1685	1165	1377	2273	3457	3222	2193	2982	21644				
615	57	1520	934	752	1683	1159	1371	2262	3447	3215	2118	2972	21433				
614	58	1465	924	732	1680	1153	1365	2251	3437	3209	2044	2963	21222				
613	59	1410	914	711	1678	1148	1359	2240	3426	3202	1969	2954	21010				
612	60	1355	904	691	1675	1142	1353	2229	3416	3195	1894	2945	20799				
611	61	1300	887	681	1670	1137	1347	2218	3406	3189	1820	2936	20589				
610	62	1245	870	671	1665	1131	1341	2207	3396	3182	1745	2926	20378				
609	63	1190	853	660	1661	1125	1334	2196	3386	3176	1671	2917	20168				
608	64	1134	837	650	1656	1120	1328	2185	3375	3169	1596	2908	19958				
607	65	1079	820	640	1651	1114	1322	2174	3365	3162	1521	2899	19747				
606	66	1039	797	629	1646	1108	1316	2162	3325	3156	1447	2836	19462				
605	67	999	774	619	1641	1103	1310	2151	3286	3149	1372	2773	19177				
604	68	958	751	609	1637	1097	1304	2140	3246	3142	1298	2710	18892				
603	69	918	728	598	1632	1091	1298	2129	3206	3136	1223	2647	18607				
602	70	878	706	588	1627	1086	1292	2118	3166	3129	1148	2584	18321				
601	71	837	683	578	1622	1080	1286	2107	3127	3122	1074	2521	18036				
600	72	797	660	567	1618	1074	1279	2096	3087	3116	999	2458	17751				
599	73	756	637	557	1613	1069	1273	2085	3047	3109	925	2395	17466				
598	74	716	614	546	1608	1063	1267	2074	3007	3102	850	2332	17181				
597	75	676	591	536	1603	1057	1261	2063	2967	3096	775	2269	16895				
596	76	635	568	526	1598	1052	1255	2052	2928	3089	701	2206	16610				
595	77	595	545	515	1594	1046	1249	2041	2888	3082	626	2143	16325				
594	78	555	522	505	1589	1041	1243	2030	2848	3076	552	2080	16040				
593	79	514	500	495	1584	1035	1237	2019	2808	3069	477	2017	15755				
592	80	474	477	484	1579	1029	1231	2008	2769	3063	402	1954	15469				

Appendix 1c. Summary of habitat areas by 5 meter depth strata used for extrapolating fish densities to fish abundance estimates by reach.

Surface elevation at time of survey was 666.5 meters, areas are in hectares. The elevation at which 5 meter analysis layers are set take in account the pool elevation and the mean layer width, eg: the 5 -10 meter layer habitat area is set 2 meters towards the center of the layer at 7m.

Reach / zones		Parsnip	Junction	Finlay	Peace	Total
Elevation	Layers	1 - 5	6 - 10, 21	11 - 20	22 - 32	1 - 32
666	surface	15044	33002	62843	30903	141792
661	3 (2.5)	12177	28915	51298	30534	122924
659	5	11031	27280	46680	30387	115377
654	10	8165	23192	35134	30018	96509
649	15	5656	20976	29552	28835	85020
644	20	3260	20009	27964	27109	78341
639	25	2989	19382	26386	25603	74360
634	30	2754	18811	20729	24468	66762
624	40	2518	16892	16634	23019	59064
619	45	1760	16676	14190	22188	54814
614	50	0	16426	12107	21222	49754
609	55	0	12950	5831	20168	38949
604	60	0	8040	3752	18892	30683
599	65	0	5701	1166	17466	24334
594	70	0	5634	0	16040	21673

Appendix 1d. Location map showing Biosonics 1988 acoustic survey transects on Williston Reservoir.



Appendix 2a. Echosounding equipment and data processing specification.

Echosounder Specifications and Field Settings:

Description	SIMRAD EY200P-P
transducer type	Single beam 70 kHz
beam angle	11.6 degree
receiver gain	3 (O dB)
pulse width (msec)	0.3
ping rate (p/sec)	medium (1.5)
time varied gain	40 log r
TVG range (m)	2 to 66
Attenuation	-15 dB
Power	1/1
Calibration	2 min. AC tone
Tape recorder	Sony TCD-D10
Record volume	3.5 fixed

Data Processing Specifications
{tc "Data Processing Specifications" \l 3}

Description	HADAS version 3.98
Interface gain	calibration tone to intersect 2 volts at 50 milliseconds
Threshold	minimum detectable target approximately - 65 dB
Field calibrations	Date, peak sphere voltage, sphere depth and threshold used for survey Aug. 26,1997 3800 mV, sphere at 11-13m, threshold 200 mV

Appendix 2b. Love's (1977) empirical relation of fish length to acoustic target strength.

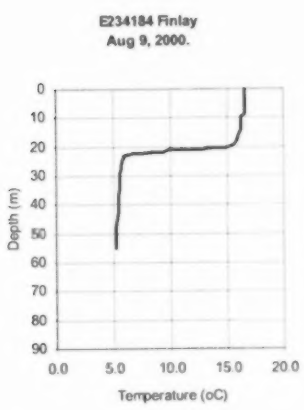
{tc "Empirical relation of fish size to acoustic target strength" \l 3}

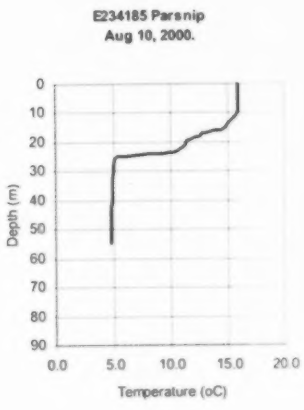
$TS = 19.1 \log_{10} (L) - 0.9 \log_{10} (F) - 62$ where TS=target strength in decibels (dB), L=length in cm and F=frequency in KHz

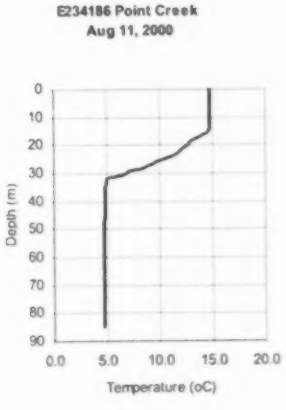
HADAS size class (db)[1]	Acoustic size range (dB)		Fish length range[2] (mm)		Fish length range[3] (mm)	
-35	-35	-33.1	325	413+	345	438+
-38	-38	-35.1	226	288	240	305
-41	-41	-38.1	158	201	167	213
-44	-44	-41.1	110	140	116	148
-47	-47	-44.1	76	97	81	103
-50	-50	-47.1	53	68	56	72
-53	-53	-50.1	37	47	39	50
-56	-56	-53.1	26	33	27	35
-59	-59	-56.1	18	23	19	24
-62	-62	-59.1	13	16	13	17

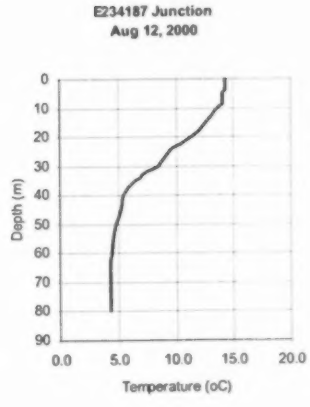
1 30 dB range in 10 size classes of 3 dB
2 from Love's (1977) empirical formula (Dorsal aspect) (F = 120 KHz).
3 from Love's (1977) empirical formula (Dorsal aspect) (F = 420 KHz).

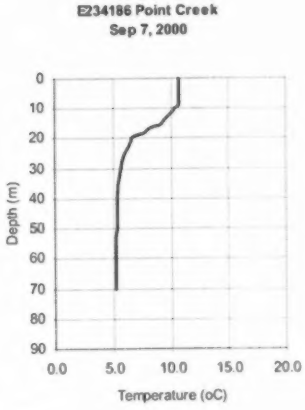
Appendix 3. Williston Reservoir water temperature profiles for August and September 2000.

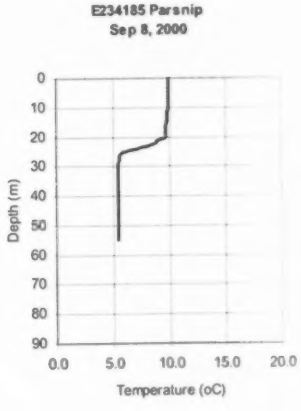


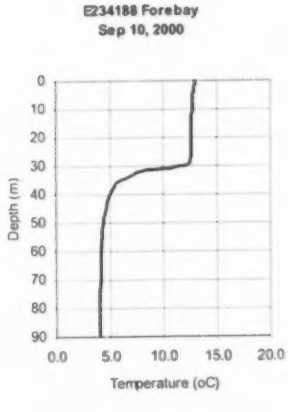












Appendix 4. Transect fish density from hydroacoustic survey

	BC Fisheries August 2000 Survey		Biosonics September 1988 Survey	
Reach	Transect number	Density (fish·ha^{-1})	Transect number	Density (fish·ha^{-1})
Parsnip	2	106	10	90
	3	64		
	4	172	12	254
			13	30
	5	63	14	62
			15	120
Junction	6	51	16	107
			17	25
	7	46	18	100
			19	64
	8	67	21	115
	9	30		
	21	39	47B	399
	10	28	23A	90
Finlay	11	107		
			25	19
	12	59		
	13	147		
	14	109	30	33
	15	120	32	30
	16	210		
	17	167	36	96
			37	81
	18	111		
			39	133
	19	219	40	74
			41	39
			43	42
Peace			48	191
	22	49	49	98
			50	25
	23	200	51	25
			52	47
	24	85	53	41
			54	14
	25	55	55	65
			56	5
	26	99		
	27	28		
			60	99
	28	17	61	208
	29	54	63	51
	30	66	65	31
	31	47	67	43
			68	83
			69	108

Appendix 5. Maximum Likelihood Estimates (MLE) and bounds of fish abundance in Williston Reservoir estimated from August 2000 acoustic surveys using Monte Carlo Simulations.

Williston Sept 2000 Systat coefficients for fish >-62 dB from 5 meter layers in 4 zones (2-5, 6-10, 11-19, 21-31)
Population estimate expanded to reservoir limnetic habitat (> 20 m depth) area surveyed

Zone	Depth	N	R^2	Density	Std Error	Habitat	Stratum pop
1	2.5	4	0.722	25.476	9.131	3260	8.31E+04
1	5	4	0.951	27.813	3.635	3260	9.07E+04
1	10	4	0.823	14.453	3.869	3260	4.71E+04
1	15	4	0.623	6.146	2.758	3260	2.00E+04
1	20	3	0.320	1.356	1.398	3260	4.42E+03
2	5	5	0.182	1.435	1.520	20009	2.87E+04
2	10	5	0.956	8.748	0.943	20009	1.75E+05
2	15	4	0.719	5.715	2.062	20009	1.14E+05
2	20	5	0.461	10.414	3.045	20009	2.08E+05
2	25	4	0.240	1.470	1.510	19382	2.85E+04
3	2.5	9	0.799	60.911	10.804	27964	1.70E+06
3	5	9	0.622	23.436	6.460	27964	6.55E+05
3	10	9	0.765	16.955	3.318	27964	4.74E+05
3	15	9	0.868	10.184	1.406	27964	2.85E+05
3	20	9	0.707	11.758	2.673	27964	3.29E+05
3	25	9	0.809	11.007	1.891	26386	2.90E+05
3	30	9	0.506	3.213	1.123	20729	6.66E+04
4	5	11	0.545	7.696	2.222	27109	2.09E+05
4	10	11	0.461	8.086	2.764	27109	2.19E+05
4	15	11	0.339	7.619	3.364	27109	2.07E+05
4	20	11	0.630	10.542	2.557	27109	2.86E+05
4	25	11	0.319	16.757	7.744	25603	4.29E+05
4	30	10	0.221	0.744	0.466	24468	1.82E+04

SYSTAT est.		MLE	
		lower	1.75E+05
zone 1	2.45E+05	Mode	2.38E+05
		upper	3.15E+05
		lower	3.85E+05
zone 2	5.55E+05	Mode	5.31E+05
		upper	7.25E+05
		lower	3.07E+06
zone 3	3.80E+06	Mode	3.73E+06
		upper	4.57E+06
		lower	8.79E+05
zone 4	1.37E+06	Mode	1.41E+06
		upper	1.87E+06
		lower	5.07E+06
Total	5.97E+06	Mode	5.92E+06
		upper	6.88E+06

Appendix 6a. Trawl sampling logs and catch data for August 2000.

Reach Parsnip			Time In	Time Out	Distance (m)	Target depth (m)	No. of layers
Station 1. Blackwater		Trawl 1	2100	2230	2612	5-35	6
Dates	Aug 30, 2000	Trawl 2	2245	0015	4309	5-35	6
Crew	DM/ML	Trawl 3	0030	0200	3518	5-35	6

Sample no.	Species	Length (mm)	Weight (g)	Age	Aging Method	Sex	Maturity	Scale no.
1	LW	254	182.1	3	S	M	MT	25
2	KO	223	143.2	2	S	F	IM	26
3	KO	40	0.7	0	L		IM	
4	LW	160	45.7	1	S		IM	26
5	KO	40	0.6	0	L		IM	
6	KO	39	0.5	0	L		IM	

Reach Junction			Time In	Time Out	Distance (m)	Target depth (m)	No. of layers
Station 2. Junction		Trawl 1	2140	2310	4061	5-35	6
Dates	Aug 28, 2000	Trawl 2	2325	0055	4401	5-35	6
Crew	DM/ML	Trawl 3	0110	0240	3865	5-35	6

Sample no.	Species	Length (mm)	Weight (g)	Age	Aging Method	Sex	Maturity	Scale no.
7	KO	161	56.7	1	S		IM	6
8	KO	166	57.5	1	S		IM	7
9	LW	79	6.7	0	S		IM	8
10	LW	160	47.2	1	S		IM	9
11	LW	242	140.8	3	S	M	IM	10
12	LW	250	139.6	3	S	M	IM	11
13	PCC	204	100.5	3	S	F	IM	12
14	CC	27	0.2					
15	KO	143	43.5	1	S			13
16	KO	161	59.6	1	S			14
17	KO	162	55.0	1	S			15
18	LW	150	40.6	1	S			16
19	LW	265	232.3	3	S	M	IM	17
20	LW	281	226.9	4	S	F	MT	18
21	KO	45	0.8	0	L			
22	LT	213	92.2	2	S		IM	19

Appendix 6a. (continued)

Reach Finlay			**Time In**	**Time Out**	**Distance (m)**	**Target depth (m)**	**No. of layers**
Station 3. Teare Creek		Trawl 1	2155	2325	2719	5-35	6
Dates	Aug 29, 2000	Trawl 2	2335	0105	4365	5-35	6
Crew	DM/ML						

Sample no.	Species	Length (mm)	Weight (g)	Age	Aging Method	Sex	Maturity	Scale no.
23	LW	245	144.5	3	S	M	IM	20
24	LW	238	144.1	3	S	M	IM	21
25	LW	250	156.4	3	S	F	M	22
26	LW	79	5.8	0	S		IM	23
27	LW	261	210.0	4	S	M	M	24
28	KO	45	0.4	0	L			

Reach Peace			**Time In**	**Time Out**	**Distance (m)**	**Target depth (m)**	**No. of layers**
Station 4. Clearwater		Trawl 1	2221	2351	4625	5-35	6
Dates	Aug 26, 2000	Trawl 2	0005	0135	3675	5-35	6
Crew	DM/ML	Trawl 3	0150	0320	4596	5-35	6

Sample no.	Species	Length (mm)	Weight (g)	Age	Aging Method	Sex	Maturity	Scale no.
29	KO	41	0.8	0	L			
30	KO	49	1.3	0	L			
31	LW	271	244.1	4	S	M	M	1
32	LW	252	201.4	3	S	F	M	2
33	LW	210	110.0	2	S	M	IM	3
34	LW	246	186.7	3	S	M	M	4
35	KO	220	122.5	2	S	F	M	5
Note: No fish caught in trawl 2								

Reach Peace			**Time In**	**Time Out**	**Distance (m)**	**Target depth (m)**	**No. of layers**
Station 5. Forebay		Trawl 1	2103	2133	1583	0-5	1
Dates	Aug 27, 2000	Trawl 2	2205	2335	3582	5-35	6
Crew	DM/ML	Trawl 3	2345	0115	4494	5-35	6

Sample no.	Species	Length (mm)	Weight (g)	Age	Aging Method	Sex	Maturity	Scale no.
Note: No fish caught in trawls 1-3								

Appendix 6a. (continued)

Reach Peace			Time In	Time Out	Distance (m)	Target depth (m)	No. of layers
Station 6. Carbon Creek		Trawl 1	0410	0540	3769	5-35	6
Dates	Aug 26, 2000						
Crew	DM/ML						

Sample no.	Species	Length (mm)	Weight (g)	Age	Aging Method	Sex	Maturity	Scale no.
36	KO	34	0.4	0	L			
37	KO	52	1.4	0	L			

Appendix 6b. GPS coordinates for start and end-points of individual trawls

Station number	Trawl number	Latitude start	Latitude end	Longitude Start	Longitude end
1	1	55°44.844	55°43.650	123°40.155	123°38.825
	2	55°43.654	55°45.326	123°38.825	123°41.688
	3	55°45.192	55°43.502	123°41.814	123°40.275
2	1	55°57.722	55°59.814	123°53.861	123°55.039
	2	55°59.660	55°57.562	123°54.903	123°52.913
	3	55°57.711	55°59.800	123°52.884	123°52.854
3	1	56°18.574	56°19.855	124°24.259	124°25.547
	2	56°19.717	56°17.456	124°25.428	124°24.222
4	1	56°02.608	56°00.830	123°09.169	123°06.049
	2	56°00.780	56°02.089	123°06.337	123°08.990
	3	56°03.208	56°01.454	123°08.564	123°05.440
5	1	56°01.970	56°02.540	122°13.961	122°14.824
	2	56°03.651	56°02.429	122°16.224	122°13.555
	3	56°02.569	56°04.437	122°13.789	122°16.548
6	1	56°05.497	56°05.640	122°55.888	122°52.273

Appendix 7a. Kokanee stocking information for Williston Reservoir, 1990-2002.

Year	Stocking Location						
	Carbon Creek[1]	Davis River[2]	Cust Creek[3]	Dunlevy Creek[4]	Manson River[5]	Nation River[5]	Total no. stocked
1990	106,500			25,000	225,000	100,000	456,500
1991	101,798			25,000	101,898	25,000	253,696
1992	193,000			25,089	72,375	163,085	453,549
1993	100,000			25,000	192,400	72,000	389,400
1994	105,000			27,398	206,198	79,000	417,596
1995	100,000			25,000	200,000	875,000	400,000
1996	100,000				204,000	100,000	404,000
1997	109,000				194,434	50,000	353,434
1998	100,040	50,000					150,040
1999		25,000	40				25,040
2000			125				125
2001			75				75
2002			150				150
Total	1,015,338	75,000	390	152,487	1,396,305	664,085	3,303,605

1. Hill Creek stock 1990-1995; Meadow Creek stock 1996-1998
2. Meadow Creek stock
3. Meadow Creek stock 1999-2000; Williston stock 2001-2002
4. Hill Creek stock
5. Hill Creek stock 1990-1995; Meadow Creek stock 1996-1997.

Appendix 7b. Kokanee spawner escapements for Williston Reservoir, 2002.

Stream	Peak Count
Osilinka R	36,790
Germanson R (Omineca R trib.)	20,000
Echo C (Omineca R trib.)	5,500
Porter C (Omineca R trib.)	5,300
Dead Bear C (Osilinka R trib.)	1,800
Unnamed C (Omineca R trib.)	1,550
Ingenika R	1,400
Jackfish C (Omineca R trib.)	1,000
Russel C (Finlay R trib.)	468
Pelly C (Ingenika trib.)	300
Unnamed C (Omineca R trib.)	150
McGraw C (Finlay R trib.)	99
Ravenol C (Swannel R trib.)	70
Aley C (Ospika R trib.)	36
Discovery C (Omineca R trib.)	2
Finlay Reach Total	**74,465**
Manson R	3,811
Scott C	50
Junction Reach Total	**3,861**
Misinchinka R	1,452
Reynolds C	475
Philip C (Nation R trib.)	193
Colbourne C	151
Parsnip R	50
Gagnon C	26
Six Mile C	21
Chichouyenily C	20
Patsuk C	17
Cut Thumb C	10
Mugaha C	8
Mischinsinlinka C	6
Parsnip Reach Total	**2,429**
Dunlevy C	191
Schooler C	20
Peace Reach Total	**211**
Total escapement estimate	**80,966**